**SOIL 4234 Laboratory**

**Lab #1**

**Chemistry Review**

## Overview

Soil nutrient management is strongly related to the behavior, in the soil, of chemical elements that are plant nutrients.  Because plants absorb nutrient elements in their ionic form, except for boron, understanding the simple inorganic chemistry of them is very useful to nutrient management.  A fundamental knowledge of chemical principles is important to understanding soil fertility and the fate of plant nutrients in the environment. The following is a review of some of the basics used in the course.

## Definitions and Relative Information

*Nutrient uptake*

* Mass flow: driven by evapotranspiration
* Diffusion: due to ion movement from area of high to area of low concentration
* Root interception: root surface contact with nutrient ions.

*Soil nutrient availability* to plants is governed by

* solubility
* ionic charge
* ionic absorption
* biological immobilization

*Solubility*: a chemical property referring to the ability for a substance (the solute), to dissolve in a solvent. Solubility is measured in terms of the maximum amount of solute dissolved in a solvent at equilibrium. Solubility of compounds and availability of soil nutrient to plants can be discussed as the following reaction: An+ + Bm- =AmBn.

*pH*: a measure of acidity/alkalinity of a solution. Unlike weakly buffered solutions, the strongly buffered solutions are resistant to small additions of a strong acid/base.

*Acid/base reaction*: acid (donates a proton) and a base (accept a proton) react to form a salt and water. During the reaction, a proton is donated by the acid to the base to yield water. The remaining ions form a salt.

*Element*: a pure substance which cannot be broken down into two or more simpler substances by the methods ordinarily available in the laboratory.

*Atom*: the smallest unit into which an element can be divided and still retain its identity as an element.

*Isotope*: one of two or more atoms that have the same number of protons but different number of neutrons (i.e. 15N, 14N).

*Compound*: a substance which can be broken down into two or more elements. The composition of a compound is always the same, formation of compounds absorbs or releases energy, the elements forming the compound lose their individual identity, and compounds are homogeneous (i.e. table salt, NaCl).

*Molecule*: the smallest unit in which a compound can exist and still retain the properties of the compound.

*Mixture*: a combination of substances that do not have a definite composition, are not homogeneous; and each component retains its individual identities (i.e. a mixture of diammonium phosphate, (NH4)2 HPO4, and potassium chloride, KCl, is a commonly used fertilizer).

*Ion*: charged atoms which make up compounds (i.e. Na+ and Cl- which make up salt).

*Cation*: a positively charged ion (i.e. Na+).

*Anion*: a negatively charged ion (i.e. Cl-).

*Avogadro's number*: the standard unit for counting atoms, 6.023X1023. This is the number of atoms in a mole of an element, molecule, compound, etc.

*Acid*: a substance that produces hydrogen ions (H+) in a water solution. A proton donor.

*Base*: a substance that produces hydroxide ions (OH-) in a water solution. A proton acceptor.

*Salt*:a compoundformed from a cation other than hydrogen and an anion other than hydroxide. The product of thereaction of an acid and a base (NaCl).

 HCl + NaOH NaCl + H2O

 acid base salt

*Buffer*: a solution which can maintain a constant hydrogen ion concentration despite moderate acid or base additions (i.e. weak acids such as ammonium acetate (NH4CH3COO) are commonly used buffers).

*Mole*: (quantity) 6.023 x 1023 molecules of a substance (element or compound).

*Molecular weight*: The weight of 6.023 x 1023 molecules of a substance. Expressed in grams per mole. Same as formula or atomic weight.

*Molarity*: (concentration) Number of moles of a substance (element or compound) per liter of solution. Expressed in moles per liter or millimoles per milliliter. Designated by letter M.

*Equivalent*: the quantity of a substance that contains or can supply 6.023 x 1023 electrical charges.

*Equivalent weight*: this quantity is measured in grams and is found by dividing the molecular or atomic weight (in grams), by the valence, or number of charges involved per formula or molecule.

*Normality (concentration)*: this is the number of equivalents of a substance (element or compound) per liter of solution. Expressed in equivalents per liter or milliequivalents per milliliter Designated by the letter N.

Periodic table: A tabulated description of chemical elements based on repeating (hence the term periodic) chemical properties. The symbol, name, atomic weight for every element can all be obtained from the periodic table. A descriptive copy of the periodic table is attached.

 **I.** **ELEMENTS AND IONS**

 A. Oxidation Number and Valence

Valence is a term used to describe charge in ions. The valence of an ion can be thought of as the number of hydrogen or hydroxide ions that it will replace or combine with in a chemical reaction. For example, two H+ will valence or combine with one O2 to form H2O, therefore the O is -2. Similarly, one OH- will combine with Na to form NaOH, thus the valence of Na is +1.

For monatomic ions (ions containing only one element), valence is the same as the oxidation number. Some elements like Fe, Cu, N, Mn, C and S have variable valences. The table below lists elements commonly encountered in soil reactions and their associated symbols, valences, and atomic weights. The information in this table will be useful throughout this course when writing chemical formulas and when expressing molar concentrations on a mass basis.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Element | Symbol  | Valence(s) | Atomic Weights |
|  |  |  |  |  |
|  | Macronutrients |  |  | grams per mole |
|  | Calcium | Ca | +2 | 40.1 |
|  | Magnesium | Mg | +2 | 24.3 |
|  | Potassium | K | +1 | 39.1 |
|  | Phosphorus | P | +5 | 31.0 |
|  | Sulfur | S | -2, +4, +6 | 32.1 |
|  | Nitrogen | N | -3, +3, +5 | 14.0 |
|  |  |  |  |  |
|  | Micronutrients |  |  |  |
|  | Manganese | Mn | +2, +4, +7 | 54.9 |
|  | Iron | Fe | +2, +3 | 55.8 |
|  | Copper | Cu | +1, +2 | 63.5 |
|  | Zinc | Zn | +2 | 65.4 |
|  | Boron | B | +3 | 10.8 |
|  | Molybdenum | Mo | +6 | 95.9 |
|  | Chlorine | Cl | -1 | 35.4 |
|  | Nickel | Ni | +2 | 58.7 |
|  |  |  |  |  |
|  | Other Elements |  |  |  |
|  | Carbon | C | +4, 0, -4 | 12.0 |
|  | Hydrogen | H | +1 | 1.0 |
|  | Oxygen | O | -2 | 16.0 |
|  | Sodium | Na | +1 | 23.0 |
|  | Aluminum | Al | +3 | 27.0 |
|  | Silver | Ag | +1 | 107.8 |
|  | Lithium | Li | +1 | 6.9 |

When more than one element combine to form an ion, they are called polyatomic ions. Some polyatomic ions commonly encountered in soil reactions are listed in the following table.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Name |  | Symbol | Valence | Molecular Wt. |
|  |  |  |  |  | (g/mole) |
|  |  |  |  |  |  |
|  | Ammonium |  | NH4+ | +1 | 18.0 |
|  | Hydroxide |  | OH- | -1 | 17.0 |
|  | Acetate |  | CH3COO-(Oac-) | -1 | 59.0 |
|  | Nitrate |  | NO3- | -1 | 62.0 |
|  | Phosphate |  | PO43- | -3 | 95.0 |
|  | Carbonate |  | CO32- | -2 | 60.0 |
|  | Sulfate |  | SO42- | -2 | 96.1 |
|  | Borate |  | BO33- | -3 | 58.8 |
|  | Molybdate |  | MoO42- | -2 | 159.9 |

 B. Nomenclature of Chemical Compounds

 Certain common names like water and ammonia are still widely used. However, common names are often not suitable for describing compounds in chemistry. A systematic naming system was developed to relate a compound's name to its composition, and in some cases, its structure. Following is a brief discussion of some of the rules of chemical nomenclature that will be used throughout this course.

 1. Cations "ic" and "ous"

 For cations having two valence states, **the higher valence is ic and lower valence is ous.**

 Examples: Cu1+ is cu prous and Cu2+ is cupric.

Fe2+ is ferrous and Fe3+ is ferric.

 Difficulties arise in the use of this method since some elements form more than two compounds (e.g., manganese). Furthermore, the system requires that all the possible valences of a metal be known in order to assign the proper suffix. **The 2+ state of iron is its lower (ferrous); the 2+ state of copper is its higher (cupric). Reduced = ous Oxidized = ic**

 Albert Stock developed an alternative system of nomenclature. The valence of the metal, in Roman numerals, is indicated after the English name of the multivalent metal; suffixes for the metals are not employed. Thus: FeCl2 is iron(II) chloride; FeCl3 is iron(III) chloride; Cu2O is copper(I) oxide. The number applies to the valence of the metal (or more properly the oxidation number) and not to any numbers appearing as subscripts in the formulas.

 2. Anions

 (a) Binary Compounds ‑ "ide"

 Ionic binary compounds are named with the metal first and the nonmetal second. For all binary compounds, the ending "ide" is substituted for the usual ending of the element appearing last in the name (i.e. NaCl, sodium chloride). However, not all compounds ending in "ide" are binaries; there are a few exceptions, such as the cyanides (e.g., NaCN) and the hydroxides (e.g., NaOH).

 (b) Ternary compounds contain three elements(i.e. KNO3). Two of the elements together form an anion. The suffixes -ite and -ate are used to denote the valence state of the anion.

 "ite" refers to the valence of some element combined with oxygen to form an anion when this element is not in its highest valence state.

 Example: NO2- nitrite -nitrogen is in a +3 valence but also

 has a +5 valence.

"ate" refers to some element combined with oxygen to form an anion when the particular element is in its highest valence states. These are more common.

 Example: NO3- nitrate -nitrogen is in a +5 valence

 3. Aqueous Solutions (aq) and Hydrated Ions

 In aqueous solutions, each ion is closely associated with a few water molecules; in fact, the formation of these hydrated ions is largely responsible for the behavior of ionic compounds in water. These aqueous, or hydrated, ions are usually indicated by the symbol (aq), placed after the formula. The number of water molecules closely associated with a given ion is not indicated, and in many cases is not known. In addition to a primary sheath of water molecules, other water molecules are loosely associated with the ions.

 Frequently, hydrated ions remain in crystalline salts obtained from evaporation of water from aqueous solutions. Common examples are Fe Cl3 x 6H2O (ferric chloride hexahydrate) and CaSO4 x 2H2O (Calcium sulfate dihydrate, or gypsum). The water molecules may be associated with an anion or cation in the compound or not specifically associated with either. Compounds that contain a salt and water combined in definite proportions are called hydrates.

1. Acids and alkalies

 Compounds that dissociate in water solution to produce H30+, or H+ (aq), ions are called acids.

 H2O

 HNO3 H+ + NO3-

 Alkalies are compounds containing a metal cation and the hydroxide ion, OH-.

 H2O

 NaOH Na+ + OH-

 An alkali and an acid react in water by a neutralization reaction. A salt composed of the cation of the alkali and the anion of the acid may be obtained by evaporating a solution derived from a neutralization reaction.

 NaOH + HNO3  Na+ + NO3- + H+ + OH- NaNO3 + H2O

 The usual ternary acids derived from oxygenated anions are named according to the name of the central element (the element other than oxygen) to which the ending "ic" is added. Thus H3PO4 is phosphoric acid. Often there are two ternary acids containing the same elements. In such instances, the endings "ic" and "ous" are used to distinguish between them, the "ous" ending denoting the one with the lower number of oxygen atoms. Thus HNO3 is nitric acid, and HNO2 is nitrous acid.

 Some binary compounds function as acids in water solution. The combination of the prefix "hydro" and the suffix "ic" used to indicate a water solution of a binary acid. For example, a water solution of hydrogen chloride, HCl, is called hydrochloric acid. The names of salts of binary acids have the customary "ide" ending.

 NaOH + HCl Na+ + Cl- + H+ + OH- NaCl (sodium chloride) + H2O

 **II. WEIGHTS AND CONCENTRATIONS**

1. Molarity and Normality Relationships

Remember the following when converting between molarity and normality.

M = 

 B. Normal (this takes into account the charge of a substance).

 1 equivalent weight, grams = molecular or atomic wt. (grams)

 valence or charges per formula

 milliequivalent weight, grams = equivalent weight (grams)

 1000

 N = equivalents

 liter

 Examples

1. Example of the determination of equivalent weight (the mass of a substance that contains 6.023 x 1023 positive or negative charges).

 Given: Na, Ca, Na2SO4, and Al2(SO4)3 • 18H20,

 Determine: the equivalent weight of each.

 1) Na; atomic wt. = 23 g/mole, valence = 1

 equivalent wt. = 23 = 23 g/eq.

 1

 2) Ca; atomic wt. = 40 g/mole, valence = 2

 equivalent wt. = 40 = 20 g/eq.

 2

 3) Na2SO4  formula wt. = 2(23) + 1(32) + 4(16) = 142 g/mole,

 charges involved = 2

 equivalent wt. = 142 = 71 g/eq.

 2

1. Al2(SO4)3 •18H20; formula wt. = 2(27) + 3(32) + 30(16) +36(1) = 666 g/mole,

 charges involved = 6

 equivalent wt. = 666 = 111 g/eq.

 6

 (b) Examples of determination of milliequivalent weight.

Using the examples from above, one milliequivalent of:

 1) Na is 0.023g. or 23 mg/meq.

 2) Ca is 0.020g. or 20 mg/meq.

 3) Na2SO4 is 0.071g. or 71.0, mg/meq.

 4) Al2(SO4)3 • 18H20 is 0.111g. or 111 mg/meq.

In each case, ... 6.02 x 1023 ÷ 103, or 6.02 x 1020 positive or negative charges are supplied.

 C. Proportionalities

 Proportionalities are used throughout this course to describe concentrations of chemicals in soil or in solutions. Proportionalities do not have units, so when performing calculations with proportionalities the units do not change.

 Two common proportionalities are percent (%) and parts per million (ppm). Percent can be defined as parts per 100 parts. The ratio of ppm to percent is 1,000,000/100 or 10,000; therefore, to convert percent to ppm, multiply by 10,000. We will commonly be dealing with ppm in our class in terms of milligrams per kilogram (mg/kg). When dealing with dilute solutions that have specific gravities close to that of water (1.0 g/ml), we can appropriately substitute l in for "kilogram" in the denominator since 1 kg of water = 1 l at 25°C.

 Another proportionality commonly used in this course is pounds per acre (lb/acre). Because an acre-furrow-slice (an acre 6 inches deep) is assumed to weigh 2,000,000 lbs., lbs/acre is the same as parts per 2 million. Therefore, to convert percent or ppm to lbs/acre, multiply by 20,000 or 2, respectively.

 Some comparative definitions:

 if 1% is then 1 ppm is

 (a) 1 lb. out of 100 lbs. 1 lb. out of 1,000,000 lbs.

 (b) 1 g. out of 100 g. 1 g. out of 1000 kilograms or

 1,000,000 g.

 (c) 1 mg out of 0.1 g. 1 mg out of 1.0 kilogram

 (d) 1 mg in 0.1 ml 1 mg in a liter

 Example 1.

 Given: a group of 100 students, of which 27 are female. Determine: (a) the % of females, (b) the ppm females.

 (a) % =  x 100

 % females =  x 100 = 27

 (b) ppm =  x 1,000,000

 ppm females =  x 1,000,000 = 270,000 or ppm = % x 10,000

 = 27 x 10,000

 = 270,000

 Example 2.

 Given: 0.01 g of cadmium (Cd) is found in 250g of sewage sludge. Determine: (a) % Cd in sludge, (b) ppm Cd in sludge.

 (a) % Cd =  x 100 = 0.004

 (b) ppm Cd =  x 1,000,000 = 40

**III. pH, Exponents, and Logarithms**

 A. pH

 pH is defined as the negative logarithm of the hydrogen ion activity (pH = -log aH). For our purposes, the concentration of hydrogen ion approximates the activity (aH = [H+]). In every liter of pure water, 1 x 10-7 moles of water are dissociated into 1 x 10-7 moles of H+ and 1 x 10-7 moles of OH-.

 H2O H+ + OH-

#  pH = -log 10-7 = 7

#  pOH = -log 10-7 = 7

 Therefore pOH + pH = 14.

 pH and pOH are related to the normality of acids and bases. The table below gives normalities of pH and pOH units.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | pH | Acid(normality of H) | Alkaline(normality of OH) | pOH |
|  |  0 | 1.0 | 0.000,000,000,000,01 |  14 |
|  |  1 | 0.1 | 0.000,000,000,000,1 |  13 |
|  |  2 | 0.01 | 0.000,000,000,001 |  12 |
|  |  3 | 0.001 | 0.000,000,000,01 |  11 |
|  |  4 | 0.0001 | 0.000,000,000,1 |  10 |
|  |  5 | 0.00001 | 0.000,000,001 |  9 |
|  |  6 | 0.000001 | 0.000,000,01 |  8 |
|  |  7 | 0.000,000,1 | 0.000,000,1 |  7 |
|  |  8 | 0.000,000,01 | 0.000001 |  6 |
|  |  9 | 0.000,000,001 | 0.00001 |  5 |
|  |  10 | 0.000,000,000,1 | 0.0001 |  4 |
|  |  11 | 0.000,000,000,01 | 0.001 |  3 |
|  |  12 | 0.000,000,000,001 | 0.01 |  2 |
|  |  13 | 0.000,000,000,000,1 | 0.1 |  1 |
|  |  14 | 0.000,000,000,000,01 | 1.0 |  0 |

 The following is the range of pH commonly encountered in soils in the U.S.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | pH | 5.5 | 6.0 | 6.5 | 7.0 | 7.5 | 8.0 |  8.5 |
|  | **Strongly acid** | **Medium****acid** | **Slightly****acid** | **Very****slightly****acid** | **Very****slightly****alkaline** | **Slightly****alkaline** | **Medium****alkaline** | **Strongly****alkaline** |

 B. Exponents and Logarithms

 Since calculation of pH involved the use of logarithms the following is a refresher on exponents and logarithms:

 y \* y \* y = y3;   =  x  = 

 ; 

 (10N) \* (10M) = 10 N+M

 In general, we can always write any number X as another number A raised to a power y, where y need not and usually is not an integral (whole steps). That is, X = Ay.

 The exponent y is called the logarithm of X to the base A and is written as follows: logAx = y

 Logarithms to the base 10 are called common logarithms, and the symbol "log" is then used without indicating the base. Another base for logarithms that is widely used is the Napier or natural base, e = 2.71828. Natural logarithms are indicated by the symbol "ln". Since logarithms are exponents, the rules for multiplication using logarithms are:

  log (xy) = log x + log y

 log(x/y) = log x - log y

 log 100 = log 1 = 0 log(xn) = nlog x

 C. Examples

 It is possible to calculate the pH from the concentration of a compound. It is important to note whether the concentration is in molarity or normality. This becomes important whenever there is more than one hydroxide anion per mole.

1. Molarity; Calculate the pH of 0.0003 M Ca(OH)2

 [OH] = 

 (there are 2 OH- anions per mole of Ca(OH)2)

 [OH] = 0.0006 or 6 x 10-4 M

 - log of 6 x 10-4 = - log 6 + (-log 10-4)

 = -0.778 + 4

 pOH = 3.22

 pH = 14 - pOH = 10.78

2. Normality Calculate the pH of 0.0003 N Ca(OH)2

Remember, normality describes the moles of change per liter of solution, not the moles of a particular compound or ion.

 [OH] = 0.0003 N = 0.0003 M = 3 x 10-4 M (there are two moles of hydroxide anions per mole of Ca(OH)2 but only one per mole of charge, or equivalent).

 - log of 3 x 10-4 = - log 3 + - (log 10-4)

 = -0.477 + 4 = 3.52

 pOH = 3.52

 pH = 14- pOH = 10.48

 **IV. ACID-BASE REACTIONS (NEUTRALIZATION)**

 The formation of a salt by the addition of an acid to a base is called neutralization. In a neutralization reaction, we are primarily interested in determining the amount of an acid or base that is present. This is accomplished by adding known amounts of a base or an acid to the solution until an endpoint is reached. This process is called titration.. When the endpoint is reached, the following relationship exists:

 equivalents of base = equivalents of acid (or meq base = meq acid)

 and since N = meq, then ml x N = meq

 ml

 therefore, ml base x N of base = ml acid x N of acid

 The endpoint of a titration can be determined by the use of an indicator. Indicators are generally acids of fairly high molecular weight. In water or other solvents, they behave as weak acids or bases and participate in equilibrium reactions involving the hydrogen ion. The association and dissociation reactions of indicators are as follows:

 HIn H+ + In-

 (acid color) (base color)

 Incidentally, oxidation-reduction indicators work in a similar manner by changing color in the presence of an oxidizing or reducing environment.

 **V. DILUTIONS**

 The relationships that we found in acid‑base reactions can also be applied to dilution problems.

 volume of solution 1 x concentration of solution 1 = volume of solution 2 x concentration of solution 2.

 V1C1 = V2C2

 Example: If we were to dilute 5 ml of a 1 N NaOH solution in 95 ml of distilled water to give a new solution volume of 100 ml, what would be the concentration of this new solution?

 V1 C1 = V2 C2

 (5 ml) x (1 N) = (100 ml) (X) X = (5 ml)(1 N)

 X = 0.05 N (100 ml)

 Often it is necessary to dilute a solution more than once to determine its concentration. This is especially true for soil and plant analysis. For example, the extraction of Ca2+ from a soil sample of 20 g with 100 ml of extracting solution. Before analysis of the extracting solution it is diluted twice, each time diluting five ml of the solution to 100 ml with water. Upon analysis of the final dilution it is found that 2 ppm of Ca2+ are present. What is the concentration of Ca2+ in meq Ca2+/100 g of soil?

 2 ppm = 2 μg/ml; Note: the diluted volume is placed over the undiluted volume.

 2 μg 100 ml 100 ml 100 ml 2 x 106 μg Ca2+ 4000 μg Ca2+

 \_\_\_\_\_\_\_ x \_\_\_\_\_\_\_\_\_\_ x  \_\_\_\_\_\_\_\_\_\_ x \_\_\_\_\_\_\_\_\_\_ = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

 ml 5 ml 5 ml 20 g soil 500 g soil 1 g soil

 The dilution factor is obtained from multiplying the quotients of each dilution.

  = 5 x 20 x 20 = 2000

To convert this to meq Ca2+/100 g soil:

4000 μg Ca2+1 mg Ca 1 mmole Ca 2 meq (+) 0.199 meq Ca2+ 19.9 meq Ca2+

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ x \_\_\_\_\_\_\_\_\_\_ x \_\_\_\_\_\_\_\_\_\_\_\_ x \_\_\_\_\_\_\_\_\_\_\_ = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

 1 g soil 1000 μg Ca 40.1 mg Ca mmole Ca g soil 100 g soil

 (molecular weight of Ca is 40.1. Charge is +2, so 2 equiv/mole or 2 meq/mmole)

To convert this to cmol(+)/kg soil:

4000 μg Ca2+1 mg Ca 1 mmole Ca 1 cmol Ca 2 cmol(+) 1000 g soil 19.9 cmol(+)

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ x \_\_\_\_\_\_\_\_ \_\_ x \_\_\_\_\_ \_\_\_\_\_\_\_ x \_\_\_\_\_\_\_\_ \_\_ x \_\_\_\_\_\_\_\_\_\_\_ x \_\_\_\_\_\_\_\_\_\_\_\_\_ = \_\_\_\_\_\_

 1 g soil 1000 μg Ca 40.1 mg Ca 10 mmol Ca 1 cmol Ca 1 kg soil kg soil

 Usually in the analysis of soils, an extract of soil is analyzed in ppm (μg /ml) of the element of interest. In order to complete the actual concentration ofthe element in the soil, two steps must be taken:

 1. Calculation of a dilution factor to convert ppm in the extract to ppm in the soil.

 2. Conversion of ppm in the soil to meq/100 g soil or cmol(+)/kg soil.

 Note:

 1. The elements Ca, Mg, K and Na are expressed as meq/100 g soil and P, S, and the micronutrients are expressed as ppm.

1. Conversion of ppm or meq/100 g to lbs./acre relies on the assumption that an acre 6" (acre furrow/slice) of soil weighs 2 x 106 lbs.

 Examples of Dilutions

 25 g of soil is extracted with 100 ml of ammonium acetate (1:4 dilution). The extract is then diluted twice, each time diluting 10 ml to 100 ml with water (1:10 dilution). Analysis of the final dilution yields 6 ppm Ca.

 Calculate: ppm Ca in soil; meq Ca/100 g soil; and lbs./acre Ca.

 6 μg 100 ml 100 ml 100 ml 2400 μg

 \_\_\_\_\_\_\_ x \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ x \_\_\_\_\_\_\_\_ x \_\_\_\_\_\_\_\_\_  = \_\_\_\_\_\_\_\_\_\_\_\_ Ca or 2400 ppm of Ca in soil.

 ml 25 g soil 10 ml 10 ml g soil

 Therefore, the dilution factor to convert ppm in the extract to ppm in the soil is 400.

 This completes step one. Next convert to meq/100 g soil.

 2400 μg Ca 1 mg 1 mmole 2 meq 0.119 meq Ca 11.9 meq Ca

 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ x \_\_\_\_\_\_\_\_\_\_\_\_ x \_\_\_\_\_\_\_\_\_\_\_\_ x \_\_\_\_\_\_\_\_\_ = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ or \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

 g soil 1000 μg 40.1 mg mmole g soil 100 g soil

 Note: Molecular weight of Ca is 40.1 and charge is 2+ (so equivalent weight of Ca is 40.1/2 = 20).

To obtain lbs./acre:

 2400 ppm Ca 2400 lbs. Ca 2 x 106 lbs soil 4800 lbs. Ca

 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ x \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

 in soil 1 x 106 lbs soil 1 acre 6 " deep 1 acre 6" deep

 Try working these examples yourself using the previous examples as a guide.

 Example 1. Given 50 g of soil are extracted with 200 ml Of NH4OAc.

 The extract is diluted by a factor of 25. Upon analysis of the final solution,

 4 ppm of K+ are found.

 Calculate: a. ppm of K in soil

 b. pp2m of K in the soil

 c. lbs./acre of K

 d. meq K/100 g of soil

 Answer: a. 400 ppm K

 b. 800 pp2m K

 c. 800 lbs. K/acre 6"

 d. 1.02 meq K/100 g soil

 Example 2. You receive an analysis from a soil testing lab reporting 0.98 meq K/100 g soil.

 Convert this to: a. ppm K in soil (using 39.1 g/eq. K)

 b. lbs. K/acre 6"

 Answer: a. ppm K = 383.18

 b. 766.36 lbs. K/acre 6"

 Example 3. Convert 100 lbs. P/acre 6" to ppm P.

 Answer: 50 ppm P

 Example 4. A 5 g soil sample is leached with NH40Ac for the determination of CEC. After distillation of the sample, 12.5 ml of 0.10 N H2SO4 solution is needed to titrate the boric acid indicator to its endpoint. Calculate the CEC of the soil.

 Answer: 25 meq/100 g

 Example 5. A lab reports a Ca/Mg ratio of 2.1 (meq Ca/meq Mg) and a concentration of Ca in your soil of 1600 ppm.

Calculate: a. meq Ca/100 g soil

b. meq Mg/100 g soil

c. ppm Mg

Answer: a. 8 meq Ca/100 g

 b. 3.81 meq Mg/100 g

 c. 462.9 ppm Mg

 Example 6. 40 g of soil is extracted with 120 ml of NH4OAc.

5 ml of extract is diluted to 120 ml with water.

You know that this soil contains 0.16 meq Na/100 g soil. What concentrations of Na (in ppm) do you expect to find upon analysis of the final dilution?

Answer: 0.51 ppm Na+

 **VI. OXIDATION-REDUCTION REACTIONS**

 Oxidation is the process which results in the loss of one or more electrons by atoms.

Fe2+ - e- Fe3+  or Fe2+ Fe3+ + e-

Reduction is the process which results in the gain of one or more electrons by atoms.

Fe3+ + e- Fe2+

An oxidizing agent is one that gains electrons and is reduced to a lower valence state.

2(+l) 2(+6) 7(-2) 2(+3)

K2 Cr2 07 + 6e- 2 Cr3+ + …

 A reducing agent is one that loses electrons and is oxidized to a higher valence state.

 +2 -2 +3

 Fe S04 - e- Fe3+ + …

 To determine the equivalent weight of oxidizing or reducing agents or to balance redox equations one must know the oxidation number of the element. The oxidation number of an element is a number which, applied to that element in a particular compound, indicates the amount of oxidation or reduction which is required to convert one atom of the free state to that of the compound. The following rules apply to the determination of oxidation numbers.

 1. The oxidation number of the free or uncombined element is 0.

 2. The oxidation number of the hydrogen ion has a value of +1.

3. The oxidation number of oxide oxygen is -2.

 4. The oxidation number of a metal in a compound is usually positive.

 5. The oxidation number of a radical or ion is equal to the electrical charge.

 6. The oxidation number of a compound is always zero and is determined by the sum of the individual atoms each multiplied by the number of atoms of the element in the molecule.

A. Balancing Redox Equations

 To balance a redox equation follow these steps:

 Example: Take the reaction of K2Cr2O7 with FeSO4 in the presence of H2SO4:

K2Cr2O7 + H2SO4+ FeS04 Cr2(SO4)3 + Fe2(SO4)3 + K2SO4 + H2O

 1. First assign oxidation numbers to each atom:

 +1 +6 -2 +1 +6 -2 +2 +6 -2

 K2 Cr2 O7 + H2 S O4 + Fe S O4

 +3 +6 -2 +3 +6 -2 +1 +6 -2 +1 -2

 Cr2 (S O4)3 + Fe2 (S O4)3 + K2 S O4 + H2O

 2. Identify the oxidizing and reducing agents by the change in their oxidation number and set up a partial equation for each.

 a. The oxidizing agent in this reaction is K2Cr2O7 because the Cr6+ ion gains electrons and is reduced to Cr3+.

 +6 +3

 K2Cr2O7 + 6e- Cr2(SO4)3

 b. The reducing agent is FeS04 because the Fe2+ ion loses an electron and is oxidized to Fe3+.

 +2 +3

 FeS04 - 1e- 1/2Fe2(SO4)3

 3. Balance the number of electrons exchanged in the reaction by multiplying the oxidizing agent by 1 and the reducing agent by 6. The equation then becomes:

 K2Cr2O7 + H2SO4 + 6FeSO4 Cr2(SO4)3 + 3Fe2(SO4)3 + K2SO4 + H2O

1. The coefficients of H2SO4  and H2O are still unknown. If we add the number of sulfates (SO4) on each side of the equation we see that the coefficient for H2SO4 must be 7 and therefore 7 for H2O. The balanced equation is:

 K2Cr2O7 + 7H2SO4 + 6FeSO4 Cr2(SO4)3 + 3Fe2(SO4)3 + K2SO4 + 7H2O

B. Determination of Equivalent Weights of Oxidizing and Reducing Agents.

 The equivalent weight (eq. wt) of an oxidizing or reducing agent is equal to the molecular weight of that substance divided by the total electron change per formula unit.

 Example: The reaction of K2Cr2O7 with FeSO4 required one mole of K2Cr2O7 and six moles of FeSO4. An electron change of six electrons occurs between one formula unit of K2Cr2O7 and 6 formula units of FeSO4. Therefore:

 eq. wt K2Cr2O7 = molecular wt K2Cr2O7 (3 e-/Cr x 2 Cr/mol wt = 6 e-)

 6

 eq. wt FeSO4 = molecular wt FeSO4 (1e-/Fe x 1 Fe/mol wt = 1 e-)

 1

 **VII. EXAMPLES OF CONVERSIONS**

 The following are some conversions that will be used frequently in this class. The examples use rounded atomic weights to simplify the presentation.

1. Converting between meq/100 g, cmole+/kg and ppm

Due to convention, most soil testing labs report ion concentrations in meq/100 g soil. It is important that we understand how to convert meq/100 g to units more commonly used in the scientific community. The System International (SI) unit to express cation exchange capacity (CEC) is cmole+/kg. Both meq/100g and cmole+/kg define the number of charges or quantity of ions per unit mass of soil, but do not quantify the mass of a particular element or ion in the soil. Therefore, we must also be able to convert these units to a mass concentration unit such as ppm.

When converting meq/100g to cmole+/kg, remember the following:

|  |  |  |  |
| --- | --- | --- | --- |
|  | 1 equivalent | = | 1 mole (6.023 x 1023) positive or negative charges |
|  | 1 cmole+ | = | 1/100 mole of charge |
|  | 1 meq | = | 1/1000 mole of charge |

Example: Given 1.0 meq Ca+2 per 100 g soil, determine the cmole+ Ca+2/Kg soil.

Using dimensional analysis, cancel the units first, then perform any needed calculations:

x

x

x

x

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | 1 meq Ca+2 | 1 eq charge | 1 mole charge | 100 cmole+ | 1000 g |
|  | 100 g soil | 1000 meq | 1 eq charge | 1 mole charge | 1 kg |

Therefore:

= 1

x

x

x

x

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | 1 |  | 1 |  | 1 |  | 100 cmole+ |  | 1000 |
|  | 100 |  | 1000 |  | 1 |  | 1 |  | 1 |

After all that work, we learn 1 meq/100 g = 1 cmole+/kg

To convert either meq/100 g or cmole+/kg to ppm in the soil, we must first know the number of charges per mole of the ion. This is determined by the valence. For example Mg+2 has a valence of 2, therefore for every mole of Mg+2, there are 2 moles of charge.

Example: Convert 4 meq Ca+2/100 g to ppm.

x

x

x

x

x

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | 4 meq |  | 1 eq |  | 1 mole charge |  | 1 mole Ca+2 |  | 40 g Ca |
|  | 100 g soil |  | 1000 meq |  | 1 eq |  | 2 mole charge |  | 1 mole Ca+2 |

= 800 ug Ca+2/g = 800 ppm Ca+2 in soil

|  |  |
| --- | --- |
|  | 106 ug |
|  | 1 g |

We can also use equivalent wt to convert between meq/100 g and ppm.

Equivalent wt = atomic wt (e.g. Ca+2: equiv. wt = 40.1 = 20 g)

 valence 2

Solving the same example as above:

=

x

x

x

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| = 800 ppm Ca+2 | 4 meq |  | 1 eq |  | 20 g |  | 106 ug |  | 800 ug |
|  | 100 g |  | 1000 meq |  | 1 eq |  | 1 g |  | 1 g |

Below is a similar example, this time using cmole+/kg as our starting units.

Convert 2 cmole+ Al+3/kg to ppm

=

x

x

x

x

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | 2 cmole+ Al+3 |  | 1 mole+ |  | 1 mole Al+3 |  | 27 g |  | 1000 mg |
|  | kg soil |  | 100 cmole+ |  | 3 mole+ |  | 1 mole Al+3 |  | 1 g |

= 180 ppm Al+3

|  |  |
| --- | --- |
|  | 180 mg Al+3 |
|  | kg soil |

Again, this time using equivalent wt:

=

x

x

x

x

= 180 ppm Al+3

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 2 cmole+ Al3 |  | 1 mole |  | 1 eq |  | 9 g |  | 1000 mg |  | 180 mg Al+3 |
| 1 kg soil Equivalent wt |  | 100 cmole+ |  | 1 mole |  | 1 eq |  | 1 g |  | kg soil |

 B. Conversion of ppm to lbs/acre.

 A conversion commonly used when reporting soil test data to farmers is to express concentrations in lbs/acre. This is usually done by assigning a certain depth and weight to the tillage zone or furrow slice. Convention has accepted that the furrow slice of an acre weighs 2,000,000 lbs. It can be derived from the following assumptions:

 Density: Agriculture soils have a bulk density (or dry weight per unit volume)

 of 1.0 to 1.8 g/cm3. Most are near 1.2 g/cm3.

 Area: An acre is about 207 ft x 207 ft, or 39,805,752 cm2.

 Volume: If you plow 8 inches deep (20 cm) your acre furrow slice

 (one acre 8 inches deep) has a volume of 796,115,040 cm3.

 Weight: If you assume a bulk density of 1.2 g/cm3 the dry weight of

 your 796,115,040 cm3 furrow slice is 955,338,040 grams.

 Since 1 lb. = 454 grams this equals 2,104,269 lbs., or

 about 2,000,000 lbs.

 Therefore: 1 lb/acre = 1 lb. per 2,000,000 lbs, or 1 pp2m. If your

 soil test results are reported in ppm, multiplying by 2

 will convert them to lbs./acre or lbs./acre furrow slice.

 Example: A soil test reports extractable P as 32 ppm. How many

 lbs/acre P are there?

 32 ppm P x 2 = 64 lbs/acre.

 C. Conversion of meq/100 g to lbs/acre.

 Example: Given 0.5 meq K, 3.7 meq Ca+2 and 1.7 meq Mg+2, how many

 lbs./acre of each exchangeable cation are present?

 0.5 meq K+ 39 mg K+ 1000 g 195 mg

 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ x \_\_\_\_\_\_\_\_\_\_\_\_\_ x \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ = \_\_\_\_\_\_\_\_\_ = 195 ppm

 100 g meq 1 kg 1 kg

 195 ppm K x 2 lbs/acre/ppm = 390 lbs K/acre

 3.7 meq Ca+2 20 mg Ca+2 1000 g 740 mg

 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ x \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ x \_\_\_\_\_\_\_\_\_\_\_\_\_\_ = \_\_\_\_\_\_\_\_\_\_\_\_\_ = 740 ppm Ca+2

 100 g meq 1 kg 1 kg

 740 ppm Ca+2 x 2 = 1480 lbs. Ca+2/acre

 1.7 meq Mg+2 12 mg Mg+2 1000 g 204 mg

 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ x \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ x \_\_\_\_\_\_\_\_\_\_\_\_\_ = \_\_\_\_\_\_\_\_\_\_\_ = 204 ppm

 100 g meq 1 kg 1 kg

 204 ppm Mg+2 x 2 = 408 lbs Mg+2/acre.