Advanced Turfgrass Management Lab Manual

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By

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INTRODUCTION

The laboratory portion of the undergraduate/graduate course, Advanced Turfgrass Management, offers the student the chance to develop specific skills while learning the application of advanced principles in turfgrass management decisions. The laboratory is an integral part of the course instruction and should be considered as such by the student. While the lecture and textbook will provide the primary source of information, the laboratory information will illustrate and reinforce concepts and principles covered in lecture. The manual allows certain Units to be selected for use depending on the instructor's preference.

The student should feel free to ask questions and discuss any subject matter in the course. While a somewhat formal laboratory procedure must be maintained to expedite completion of the activities, reasonable informality in laboratory will develop and facilitate learning.

Maximum benefit and minimum frustration will be achieved when preparation for the laboratory is completed ahead of time. This includes reading of the lab manual and review of the textbook references before the lab meets each week.

The text used for this course is:

Golf Turf Management. L. B. McCarty. 2018. CRC Press at www.crcpress ISBN 0-13-139793-1.

This is supplemented by:
Applied Soil Physical Properties, Drainage, and Irrigation Strategies by L.B. McCarty, R. Hubbard, Jr. and V. Quisenberry. Springer International Publishing Switzerland. www.springer.com ISBN 978-3-319-24224-8.

Diagnosing Turfgrass Problems: A Practical Guide by R.W. White and L.B. McCarty. www.shopping.clemson.edu. ISBN 978-0-9798777-6-6.

Best Management Practices for Carolina Sports Fields: by L. B. McCarty and Grady Miller. 2021. SC Sports Turf Managers Association, Boiling Springs, SC. 189pp.

Southern Lawns. B. McCarty (editor) available from Clemson University (EC 707) at www.shopping.clemson.edu.

It is suggested students have completed an Introductory Soils collegiate course prior to this one, although it isn't required. Also, students not comfortable with various applied mathematical and chemistry concepts, should complete Unit 1 before progressing to other Units.

UNIT 1

REVIEW OF BASIC MATHEMATICAL AND CHEMISTRY CONCEPTS

AUTO-TUTORIAL LAB

Objectives:
1. Review and expand the student's knowledge/experience on unit conversions common in science.
2. Review the use of exponential notation and logarithms.
3. Practice metric system conversions including temperatures.
4. Review the basic chemistry fundamentals relative to turfgrass science.
5. Review equivalent weights, molecular weights and dilution concentrations used in turfgrass science.

FUNDAMENTALS OF MATHEMATICS

Successful turfgrass managers possess many agronomic, biological and interpersonal skills. Having a good working knowledge of basic mathematical and chemistry principals provides a key foundation on which to build and expand these and other successful skills.

This laboratory is a self-study (auto-tutorial) review of the basic mathematical and chemistry principles turfgrass managers should understand. Advanced turfgrass management involves numerous mathematical calculations and unit conversions such as determining land areas, pesticide and fertilizer calibrations, metric conversions, etc. Chemistry knowledge is necessary when analyzing and interpreting water, soil, and tissue sample composition, handling and blending various fertilizer sources, and others. For most students, this laboratory is a review or "refresher" on these basic concepts necessary before advancing to other laboratory exercises in this manual.

Unit Conversions

Units are necessary to describe the extent numbers exist. It does no good to say than an item has a mass of seven without describing the units, for example, 7 lb, 7 oz., 7 g, 7 kg, or 7 mg. Just as numbers can be multiplied and divided, so can units. For example, the distance one goes by traveling at a speed of 50 cm/sec for 3 seconds is determined as:

$$\frac{50\ \text{cm}}{\cancel{\text{sec}}} \times 3\ \cancel{\text{sec}} = 150\ \text{cm}$$

This is an example of canceling of units common to both numerators and denominators and removal from the expression where,

$$\frac{\cancel{a}x}{\cancel{a}} = x$$

Identifying the desired end unit is the first step of successful unit analysis. This then allows the appropriate conversions to be used to obtain this.

Examples:

How many oranges can be bought for 75 cents if one dozen costs 50 cents? First, oranges is the desired end "unit."

$$75\ \cancel{\text{cents}} \times \frac{1\ \cancel{\text{dozen}}}{50\ \cancel{\text{cents}}} \times \frac{12\ \text{oranges}}{\cancel{\text{dozen}}} = 18\ \text{oranges}$$

Find the number of feet in 1.8 mile (1 mile = 5,280 feet).

$$1.8\ \cancel{\text{mile}} \times \frac{5{,}280\ \text{ft.}}{\cancel{\text{mile}}} = 9{,}504\ \text{ft.}$$

Convert 5/16 inch to mm (1 in = 2.54 cm).

$$\frac{5\ \cancel{\text{in}}}{16} \times \frac{2.54\ \cancel{\text{cm}}}{\cancel{\text{in}}} \times \frac{10\ \text{mm}}{\cancel{\text{cm}}} = 8\ \text{mm}$$

A shorter means of calculating this is possible if one knows 1 inch = 25.4 mm.

$$\frac{5\ \cancel{in}}{16} \times \frac{25.4\ mm}{\cancel{in}} = 8\ mm$$

Convert 2 x 10^6 lb/ac to kg/ha (2.47 ac are in one ha).

$$\frac{2 \times 10^6\ \cancel{lb}}{\cancel{ac}} \times \frac{0.454\ kg}{\cancel{lb}} \times \frac{2.47\ \cancel{ac}}{ha} = \frac{2{,}242{,}760\ kg}{ha}$$

If a car gets 30 miles/gallon of gas, how many kilometers could it travel on 1 liter? (1 mile = 1.61 km; 1 gal = 4 qt; and 1.06 qt = 1 L).

$$\frac{30\ \cancel{miles}}{\cancel{gal}} \times \frac{1.61\ km}{1\ \cancel{mile}} \times \frac{1\ \cancel{gal}}{4\ \cancel{qt}} \times \frac{1.06\ \cancel{qt}}{1\ L} = 12.08\ km/L$$

Using Powers of 10 – Exponentials

In most measurements of everyday affairs, we do not deal with very large or very small numbers. Our units of measurement have been chosen so that most measurements are in numbers of convenient size. In scientific work, however, measurements can vary over an enormous range of sizes. The mass of an atom would be a decimal fraction with a similarly large number of zeros to the right of the decimal point. It is clearly impractical to work with such numbers written out in full, and scientists therefore use powers of 10 to abbreviate them. An example is the number 1026. This number may be written: 1.026 x 10^3. The symbol 10^3 means "multiply by 10 three times": 1.026 x 10^3 = 1.026 x 10 x 10 x 10 or 1.026 x 1000 = 1026. Another way of interpreting this notation is to say that 10^3 means "move the decimal point three places to the right." Note that 1.026 x 10^3 = 10.26 x 10^2 = 102.6 x 10^1 = 1026. Each time the decimal point is moved one place to the right, you reduce the power of 10 by 1. Moving the decimal point to the left increases the power of 10: 1.026 x 10^3 = 0.1026 x 10^4.

When dealing with the use of exponents to express powers of numbers of algebra (x^a, etc.); measurements expressed in powers of 10 can be multiplied together or divided by one another in accordance with the rules of exponents in algebra. For example:

5.0 x 10^9 multiplied by 3.0 x 10^3 = 15 x 10^{12} = 1.5 x 10^{13}
2.4 x 10^8 divided by 8.0 x 10^5 = 0.30 x 10^3 = 3.0 x 10^2
2.0 x 10^{-24} divided by 4 x 10^{-35} = 0.5 x 10^{11} = 5.0 x 10^{10}

To add or subtract quantities expressed as powers of 10, all quantities must be converted to the same power of 10.

Example:
Add 2.7 x 10^4 and 3.8 x 10^5.
By changing the second number to 38 x 10^4. One can then add them to obtain 40.7 x 10^4 or 4.07 x 10^5 or 407,000.

Some Common Exponential Notations

$x^0 = 1$
$x^{-a} = 1 / x^a$
$x^a x^b = x^{a+b}$
$(xy)^a = x^a y^a$
$(x^a)^b = x^{ab}$
$x^a \div x^b = x^{a-b}$

$$\frac{x+y}{a} = \frac{x}{a} + \frac{y}{a}$$

$$\frac{a}{b} \div \frac{x}{y} = \frac{ay}{bx}$$

Examples:

$(a)^3 = a \times a \times a$
$3^0 = 1 = 1$
$3^1 = 3 \times 1 = 3$
$3^2 = 3 \times 3 = 9$
$3^3 = 3 \times 3 \times 3 = 27$
$3^4 = 3 \times 3 \times 3 \times 3 = 81$
$10^{-1} = \frac{1}{10} = \frac{1}{10} = 0.1$

$$10^{-2} = \frac{1}{10} \times \frac{1}{10} = \frac{1}{100} = 0.01$$

$$10^{-3} = \frac{1}{10} \times \frac{1}{10} \times \frac{1}{10} = \frac{1}{1{,}000} = 0.001$$

$$3 \times 2^{3} = 3 \times (2 \times 2 \times 2) = 24$$

$$4.1 \times 10^{3} = 4.1 \times (10 \times 10 \times 10) = 4{,}100$$

$$12{,}345 = 12.345 \times 10^{3} = 123.45 \times 10^{2} = 1234.5 \times 10^{1}$$

$$= 12{,}345 \times 10^{0} = 123{,}450 \times 10^{-1} = 1{,}234{,}500 \times 10^{-2}$$

$$0.0005 = 5.0 \times 10^{-4} = 50 \times 10^{-5} = 0.005 \times 10^{-1}$$

$$\frac{6+8}{2} = \frac{6}{2} + \frac{8}{2} = 3 + 4 = 7$$

$$\frac{2}{3} \div \frac{1}{6} = \frac{2\,(6)}{3\,(1)} = \frac{12}{3} = 4$$

The Metric System

In the English System of measurement used in the USA, neither the names nor the sizes of the units have a logical relationship to one another. There are 12 inches in a foot, 3 feet in a yard, 1760 yards in a mile, and so forth. The metric system, however, is a simple one based on the decimal relationships of the numbers in the number system. Because of the decimal relationships between units, calculations and changes from one unit to another are much easier to make. It simply involves moving the decimal point or adding or removing zeros from the original numeral. In this system, the names of relatively few basic units need to be learned. Units of other sizes are then formed by adding prefixes to the basic unit. The main disadvantage of the metric system in everyday usage is that metric units lack the practical sizes of English units. Refer to **Appendix A** for a comprehensive measurement and conversion factors between English and metric systems. The following is a list of those prefixes more commonly used:

Metric Prefix Definitions (basic metric unit = 1)

tera	=	10^{12}	deci	=	10^{-1}
giga	=	10^{9}	centi	=	10^{-2}
mega	=	10^{6}	milli	=	10^{-3}
kilo	=	10^{3}	micro	=	10^{-6}
hecto	=	10^{2}	nano	=	10^{-9}
deca	=	10^{1}	pico	=	10^{-12}

For example, a kilometer (km) is 1,000 meters; a milligram (mg) is 1/1,000 gram; and a nanosecond (nsec) is 1/1,000,000 second. *Milli*-, *centi*-, and *kilo*- are the prefixes used most. Metric units are used almost exclusively in chemistry. Some of the more important derived units in the metric system are:

Length. The basic unit of length is the meter (m). A meter (m) = 3.28 feet = 39.4 inches = 100 cm = 1.094 yd. = 1000 mm. For long distances, kilometer (km) is used which is about 0.6 miles. For short measurements, centimeter (cm) or millimeter (mm) is used (**Table 1-1**).

Table 1-1. English and metric units used in various measurements.

Measurement	English Unit	Metric Unit	Relationship
length	inch (in)	centimeter (cm)	2.54 cm/in
length	yard (yd)	meter (m)	0.91 m/yd
length	mile (mi)	kilometer (km)	1.61 km/mi
Mass	ounce (oz.)	gram (g)	28.4 g/oz.
Mass	pound (lb)	gram (g)	454 g/lb
Mass	pound (lb)	kilogram (kg)	2.21 lb/kg
Volume	cubic inch (in^3)	milliliter (ml)	16.4 ml/in^3
Volume	quart (qt)	liter (L)	0.95 L/qt

Mass (or weight). The standard of mass is the kilogram (kg). The basic unit of mass is the gram (g), which is one one-thousandth of a kg. 1 gram = 1000 mg = 0.0353 oz. = 0.001 kg = 0.002205 lb. One kilogram is 1000 g, which is about 2.2 pounds.

Volume. The basic unit of volume is the liter which is about 1.06 quarts. It is defined as one thousand cubic centimeters. One cubic centimeter (cc or cm^3) and one milliliter (ml) are equal. 1 liter (l) = 2.113
1 pt. = 1,000 ml = 1.06 qt = 33.8 fl oz. = 0.26 gal

To convert from one unit to another in the metric system requires only moving the decimal point the correct number of places (often three) (**Table 1-2**). For example, 250 ml = 0.250 L since milliliters are smaller than liters. In general, the larger the size of each one of a unit, the fewer there will be of them. Conversely, the smaller the unit, the more of them. For example, 2 m = 2000 mm since a lot of small units (mm in this case) make up the 2 large meters. Some other examples include:

0.250 m = 250 mm
29 g = 0.029 kg
520 cm^3 = 520 cc = 520 ml = 0.520 L
1µg = 0.000001 g (or 1 x 10^{-6} g)

Table 1-2. Metric unit relationships.

Size		Mass	Length	Volume
1,000 units	10^3	kilogram (kg)	kilometer (km)	kiloliter (kl)
1	1.0	gram (g)	meter (m)	liter (l)
1/10	0.1	decigram (dg)	decameter (dm)	deciliter (dl)
1/100	0.01	centigram (cg)	centimeter (cm)	centiliter (cl)
1/1,000	0.001 or 10^{-3}	milligram (mg)	millimeter (mm)	milliliter (ml)
1/1,000,000	10^{-6}	microgram (µg)	micrometer (µm)	microliter (µl)
1/1,000,000,000	10^{-9}	nanogram (ng)	nanometer (nm)	nanoliter (nl)

Examples:

How many millimeters (mm) are in 1 km?

$$1\text{ km} \times \frac{1000\text{ m}}{\text{km}} = 1{,}000\text{ m} \times \frac{1{,}000\text{ mm}}{\text{m}} = 1{,}000{,}000\text{ mm}$$

What is the area of a square 1.5 cm on each side?

$$1.5\text{ cm} \times 1.5\text{ cm} = 2.25\text{ cm}^2$$

How many hectares are in a 2 x 15 m plot?

$$2\text{ m} \times 15\text{ m} \times \frac{1\text{ ha}}{10{,}000\text{ m}^2} = 0.003\text{ ha}$$

Convert 15 ml into L and µL.

$$15\text{ ml} \times \frac{\text{L}}{1{,}000\text{ ml}} = 0.015\text{ L} \times \frac{1{,}000{,}000\ \mu\text{L}}{\text{L}} = 15{,}000\ \mu\text{L}$$

How many ml are in 5.5 L?

$$5.5\text{ L} \times \frac{1{,}000\text{ ml}}{\text{L}} = 5{,}500\text{ ml}$$

Convert 13 g into kg and µg.

$$13\text{ g} \times \frac{\text{kg}}{1{,}000\text{ g}} = 0.013\text{ kg} \times \frac{10^9\ \mu\text{g}}{\text{kg}} = 13{,}000{,}000\ \mu\text{g}$$

Temperature Scales

In temperature measurements, a long, narrow tube, the thermometer, is most often used. The thermometer often contains mercury which expands (like most substances) when its temperature rises and contracts when its temperature falls. The scale on the thermometer used to measure temperature change is either Fahrenheit (F) or Celsius (also referred to as centigrade, C). On the centigrade scale, the freezing point of water is 0 C, and the boiling point, 100 C. To convert between F and C, the following equations are used:

$$\text{degrees Centigrade} = (F - 32) \times 5/9$$

$$\text{degrees Fahrenheit} = (C \times 9/5) + 32$$

Therefore, to change C to F: multiply C by 9/5 (or 1.8) and add 32. To change F to C, subtract 32 and multiply by 5/9 (or 0.556).

Examples:

Convert 86 F to C.

C = (86 ~~F~~ - 32) x 5C / 9 ~~F~~

= (86 - 32) x 5C / 9

= 30 C

Convert 46 C to F.

F = (46 ~~C~~ x 9 F/5 ~~C~~) + 32

= [46 x 9 F/5] + 32

= 115 F

Logarithms

Logarithms are the exponents a base must be raised to obtain a particular numerical value. Two bases are commonly used: (1) base 10, for common logarithms, indicated as log_{10} or just *log*; and (2) the natural logarithm, indicated as log_e or *ln* where *e* equals approximately 2.718. Logarithms are still important in mathematically describing soil characteristics such as soil pH. The logarithm of a number is the exponent to which 10 must be raised to achieve the number.

To write the logarithm of a number, write only the exponent and not the base:

100	=	10^2		
log 100	=	log 10^2	=	2
log 1,000,000	=	log 10^6	=	6

The log of 100 is 2 and the log of 0.1 is -1 because 10^2 equals 100 and 10^{-1} equals 0.1. Numbers not a power of 10 are determined using a calculator for example, log 2 = 0.3010 and log 5 = 0.6989. Numbers less than 1 have negative logarithms, for example, log 0.03 = -1.5228 and log 0.4 equal -0.3979. Numbers less than zero are not assigned a logarithm. Mathematical operations involving logarithms are:

1. **Multiplication**, where logarithms are added: log (*NM*) = log *N* + log *M*
2. **Divisions**, where logarithms are subtracted: log *N*/*M* = log *N* − log *M*
3. **Raising to a power**, where logarithms are multiplied by the power: log C^N = *N* log *C*

Examples:

What is log (6 x 2)?	=	log 6 + log 2	or	log (6 x 2)	=	log 12
	=	0.7781 + 0.3010			=	1.0791
	=	1.0791				
What is log (1000/10)?	=	log 1000 – log 10	or	log 100	=	2
	=	3 - 1				
	=	2				
What is log 2^8?	=	8 x log^2	or	2^8	=	256
	=	8 x 0.3010		log 256	=	2.4082
	=	2.4082				

Find the logarithm of 39 and 3900:

log 39	=	log 3.9 + log 10	=	0.59 + 1	=	1.59
log 3900	=	log 3.9 + log 1000	=	0.59 + 3	=	3.59

Find the logarithm of 7.0 x 10^{-3}:

log 7.0 x 10^{-3} = log 7.0 + log 10^{-3} = 0.85 + (– 3) = -2.15

What is the logarithm of 0.065?

0.065 = 6.5 x 10^{-2} = log 6.5 + log 10^{-2} = 0.81 + (– 2) = -1.19

Examples:

What is the pH of a solution if [H^+] is 3 x 10^{-4}?

step 1: log 3 + log 10^{-4} = 0.48 + (-4) = -3.52 [H^+]

step 2: pH = -log[H^+] = -(-3.52) = 3.52

Find [H^+] in a solution of pH 7.85.

step 1: Change the pH sign: pH = -log[H^+] = -pH = log[H^+] = -7.85 = log[H^+]

step 2:	Find the number whose log is -7.85. To obtain a positive mantissa, go down one more digit in the characteristic to -8. then: $-8 + x = -7.85$ = $-8 + 0.15$ = -7.85 log -8 + log 0.15 = 1.4×10^{-8} [H^+]

Practice Problems (*answers*)

1. What is the numerical value of:
   a. 2^7 (*128*) b. $(10^2)^4$ (*10^8*)
   c. 6^4 (*1,296*) d. $(5^2)^3$ (*5^6*)

2. Convert 212 F to C (*100 C or boiling*).

3. Convert 0 C to F (*32 F or freezing*).

4. A product's label recommends mixing 4 ml of the product per 5 liters of water. Convert this to ounces per gal. (*0.102 oz./gal*).

5. A tee's measurements are 35 feet by 57 feet. What size is this in acres and hectares? (*4.58×10^{-2} or 0.0458 acres and 1.85×10^{-2} or 0.0185 hectares*).

6. If a sprayer travels 91 feet in 10 seconds, what is its speed in miles per hour (mph), meters per hour, and kilometers per hour? (*6.2 mph, 1.049×10^4 meters per hour &10.49 kilometers per hour*).

7. The height of cut for a green is ⅛-inch. List this in decimals and in millimeters (mm). (*0.125-in & 3.18 mm*).

8. Determine the following:
   $(7.8 \times 10^8) \times (4.3 \times 10^1)$ (*33.5×10^9*)
   $(4.1 \times 10^6) \div (6.3 \times 10^3)$ (*0.65×10^3* or *6.5×10^2*)
   $(5.1 \times 10^2) + (4.6 \times 10^4)$ (*46,510* or *4.651×10^4*)
   $(3.2 \times 10^{-1}) \div (1.2 \times 10^{-2})$ (*27* or *2.7×10^1*)
   $(2 \times 10^2) + (4 \times 10^2)$ (*600*)
   $(3 \times 10^3) + (5 \times 10^2)$ (*3,500*)
   $(5 \times 10^4) - (1 \times 10^4)$ (*40,000*)
   $(2 \times 10^4) - (8 \times 10^3)$ (*12,000*)
   $(2 \times 10^4) \times (3 \times 10^2)$ (*6,000,000 or 6×10^6*)
   $(5 \times 2^3) \times (6 \times 2^5)$ (*7,680*)
   $(8 \times 10^4) \div (10 \times 10^2)$ (*80*)
   $(4 \times 4^4) \div (1 \times 4^3)$ (*16*)

9. Find the log of the following:
   (a) 3×10^9 (*9.48*)
   (b) 3×10^{-9} (*-8.52*)
   (c) 460 (*2.66*)
   (d) 0.0032 (*-2.49*)
   (e) 1000 (*3*)

10. What is log 5 + log 6 (*1.4770*)

11. Find the pH of the following:
    (a) [H^+] = 10^{-3} (*3*)
    (b) [H^+] = 0.3 (*0.52*)

12. Find [H^+] for each:
    (a) pH = 5 (*10^{-5}*)
    (b) pH = 3.4 (*4×10^{-4}*)

FUNDAMENTALS OF CHEMISTRY

Chemistry is the branch of science which studies matter—its composition, properties, and changes. All processes involved in plant culture such as soil reactions, plant growth and development, pest management, and water use and quality, involve chemical reactions.

Atoms

The smallest particle of an element that has the properties of that element is an **atom**. **Molecules** are groups of two or more atoms held together by the forces of chemical bonds. Molecules are electrically neutral (no net charge). **Ions** are atoms or groups of atoms that carry positive (termed "cations") or negative (termed "anions") electrical charges.

An atom consists of two parts, the nucleus and the electron cloud (**Figure 1-1**). Every atom has a core, or **nucleus** which contains one or more positively charged particles called **protons**. The number of protons distinguishes the atoms of different elements from one another. For example, an atom of hydrogen (H), the simplest element, has one proton in its nucleus; an atom of carbon (C) has six protons. For any element, the number of protons in the nucleus of its atoms is referred to its **atomic number**. The atomic number of hydrogen (H^+) is one and the atomic number of carbon (C) is six.

Atomic nuclei also contain uncharged particles of about the same weight as protons called **neutrons**. Neutrons affect only the weight of the atom, not its chemical properties. The weight of an atom is essentially made up of the weight of the protons and neutrons in its nucleus. The **atomic weight** of an element is defined as the weight of an atom relative to the weight of a carbon atom having six protons and six neutrons and a designated atomic weight of 12. Because these atomic weights are relative values, they are expressed without units of weight. Similarly, the **atomic mass** of an element is the mass of an atom relative to that of a carbon atom with a designated atomic mass of 12.

The remainder of an atom lies around the central nucleus and is called the electron cloud. The electron cloud gives an atom its volume and keeps other atoms out since two objects cannot occupy the same space simultaneously. Within the electron cloud, electrons revolve about the nucleus similar to the planets revolving about the sun, in orbits of various diameters dependent upon on the available energy.

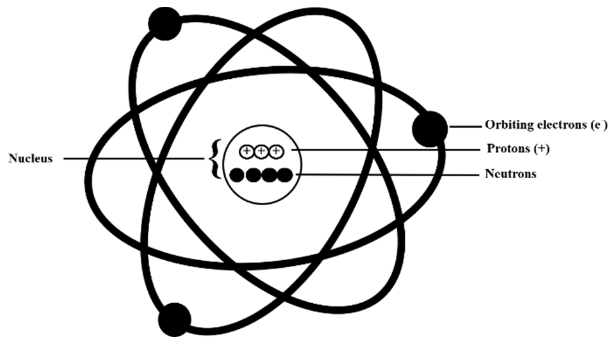

Figure 1-1. Atomic structure of lithium (Li). Atoms are made up of a relatively heavy, compact, centrally located nucleus, which contains positively charged protons and neutrally charged neutrons in an "electron cloud". Lighter, negatively charged electrons orbit about the nucleus at varying distances from its center.

An electron cloud is composed of negatively charged particles, called **electrons**. Electrons are attracted by the positive charge of the protons. The number and arrangement of electrons determine whether an atom will react with itself or other atoms, and the manner in which the reaction will occur. Due to their opposite charges, protons attract electrons, and all atoms have equal number of protons and electrons, thus, all atoms are *electrically neutral*.

atomic number = number of protons = number of electrons

Elements

Matter is anything that occupies space. A **substance** is a distinct kind of matter consisting of the same properties throughout the sample. All matter is made up of **elements**. Elements are substances that cannot be broken down into other simpler substances by ordinary chemical means. There are 92 naturally occurring elements on Earth each differing from the others by the number of protons in the nuclei of its atoms. These are referred to as *natural* elements. Examples of natural elements include iron (abbreviated Fe), oxygen (O), mercury (Hg), copper (Cu), aluminum (Al), hydrogen (H), sodium (Na), gold (Au), silver (Ag), sulfur (S), and carbon (C). Hydrogen (H) is the lightest element with only one proton in its nucleus while uranium (U) is one of the heaviest at 92. Currently, 113 total elements exist, including those that are man-made (*artificial* elements) with new ones periodically being synthesized.

Elements are composed of a single kind of atom; if it is composed of different atoms in a fixed ratio, it is referred to as a **compound**. Water (H_2O) is a compound composed of different atoms. It can be separated into simpler substances; thus, it is not an element. It separates into two different gases, oxygen (O_2) and hydrogen (H_2), which are elements. Table salt (NaCl) is also a compound composed of the elements sodium (Na) and chlorine (Cl). Table sugar or sucrose

($C_{12}H_{22}O_{11}$), is a compound formed from a combination of the three elements – carbon (C), hydrogen (H), and oxygen (O) – in a distinct ratio.

Of the more than 100 known elements, eight make up more than 98 percent of the earth's crust [oxygen (O), silicon (Si), aluminum (Al), iron (Fe), calcium (Ca), sodium (Na), potassium (K) and magnesium (Mg)].

A **mixture** consists of two or more substances (elements or compounds) physically mixed together but not chemically combined like in a compound. A **solution** (also called a mixture) with no visible differing parts (e.g., a single phase) is referred to as **homogenous**. Sugar dissolved in water produces a single-phase homogeneous mixture (or solution) of sugar water. A **heterogeneous** mixture has visibly different parts (or layers or phases). Most salad dressings, for example, have visible different parts no matter how thoroughly they are mixed and can be separated by ordinary physical means.

Grouping Elements — The Periodic Table

One of the great milestones in chemistry's evolution was the arrangement of elements into groups with similar properties. The **Periodic Table** (**Figure 1-2**) is read like a newspaper, from left to right and down the page. Each horizontal row of the Periodic Table represents a **period** or **series**. An electron is added to the valence (outer) shell of the atoms of each element as one moves from left to right within each of the seven periods.

The vertical columns of elements in the Periodic Table are called **groups** or **families**. Numbers from 1 to 18 are used to identify each group. In general, elements in the same group have similar properties and have the same number and similar arrangement of outer-shell (valence) electrons. Each element is located within a square containing the symbol, relative atomic mass, and atomic number of that element.

Example:

Fill in the following blank cells:

Element	Symbol	Atomic Number	Mass	Number of Protons	Number of Electrons	Number of Neutrons
carbon	?	?	12	?	6	?
?	K	19	?	?	?	21
?	?	12	?	12	?	12
helium	?	2	4	2	?	?
?	?	5	?	5	?	6

answers:

Element	Symbol	Atomic Number	Mass	Number of Protons	Number of Electrons	Number of Neutrons
carbon	*C*	*6*	12	*6*	6	*6*
potassium	K	19	*40*	*19*	*19*	21
magnesium	*Mg*	12	*24*	12	*12*	12
helium	*He*	2	4	2	*2*	*2*
boron	*B*	5	*11*	5	*5*	6

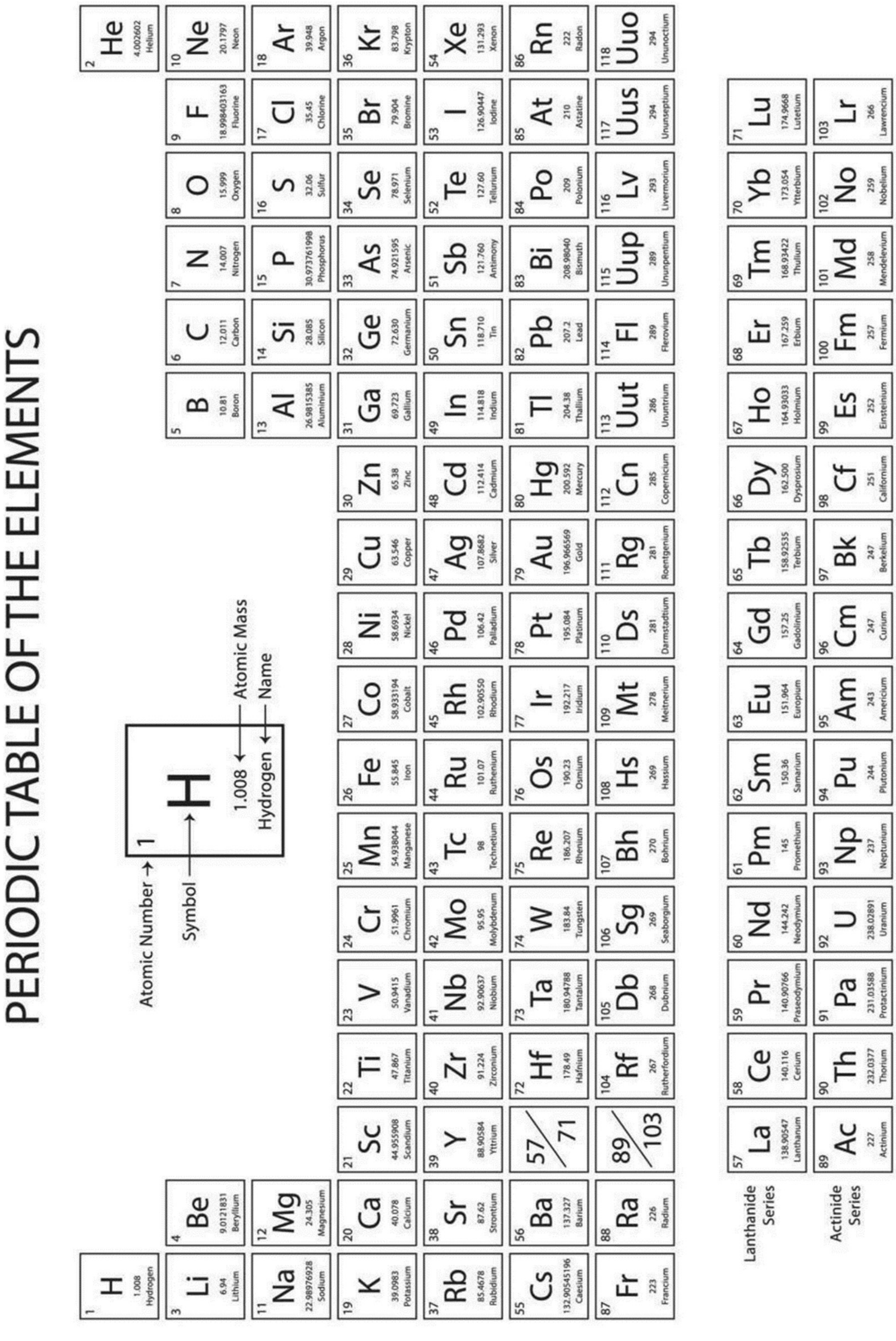

Figure 1-2. The Periodic Table of elements. Each horizontal row represents a **period** or **series** where an electron is added to the valence (outer) shell of the atoms of each element as one moves from left to right. The vertical columns of elements are called **groups** or **families**. Numbers from 1 to 18 are used to identify each group and in general, elements in the same group have similar properties and have the same number and similar arrangement of outer-shell (valence) electrons. Each element is located within a square containing the symbol, relative atomic mass, and atomic number of that element.

Solution Concentrations

Several ways exist of quantitatively expressing the relative amounts of solute and solvent or of solute and solution. Solution concentrations may be expressed in terms of weight percentage, molarity, molality, parts per million, millimoles, and equivalents. Each method has advantages when used for specific purposes.

Ways solute concentrations are expressed in chemistry.

1. Percent by weight (or mass) – used for stoichiometric calculations,
2. Parts per million (or mass/volume) – mg/kg, mg/L, 0.001%, 1 µg/g, 1 µl/ml,
3. Equivalents and milliequivalents,
4. Molarity (*M*) = number moles of solute per liter solution,
5. Millimoles (mmole) = number moles per ml solution,
6. Molality (*m*) = number moles solute per kg solvent,
7. Normality (*N*) = number grams equivalents of a solute in a solution (gram eq/L).

Molecular Weights and Concentrations

When dealing with a solution, the concentration depends upon the relative proportions of solute and solvent (which is often water). The more solute dissolved in a solvent, the more concentrated the solution becomes. Meanwhile, the more solvent added, the more dilute the solution becomes. The weight of solute per 100 grams of solvent in this solution is known as its **solubility**. At a given temperature, the terms dilute and concentrated are qualitative and chemists have developed several methods for expressing solution concentrations quantitatively.

Molecules, as well as atoms, are measured in units called **moles**. A mole is a specific number of chemical particles. One mole of any substance contains the same number of particles (atoms, ions or molecules) as 1 mole of any other substance. This number, 6.022×10^{23}, is known as *Avogadro's number*. For example, 1 mole of sodium contains 6.022×10^{23} atoms of sodium; 1 mole of chloride ions contains 6.022×10^{23} Cl^- ions; and 1 mole of water contains 6.022×10^{23} molecules of water. One can think of moles in the same way as a pair or a dozen, since each represents a numerical quantity.

1 pair	=	2 objects
1 dozen	=	12 objects
1 mole	=	6.022×10^{23} particles

The **molecular weight** of a substance is the sum of the atomic weights of all the atoms in a molecule. For example, the molecular weight of carbon dioxide, CO_2, is the sum of the atomic weights of one carbon and 2 atoms of oxygen: 12 + 16 + 16, or 44 g.

One mole of a substance weighs an amount, in grams, that is numerically equal to its atomic weight (or molecular weight). For example, the molecular weight of $CaCl_2$ is 111g; therefore, 111g of $CaCl_2$ is one mole of $CaCl_2$.

The mole is useful for defining quantities involved in chemical reactions. To form water, for example, 2 moles of hydrogen atoms and 1 mole of oxygen atoms combine to produce 1 mole of water molecules as shown: $2H_2 + O_2 \rightarrow 2H_2O$. Similarly, to make table salt (NaCl), 1 mole of sodium (about 23 grams) would combine with 1 mole of chlorine (about 35.5 grams) to form 1 mole of NaCl which weighs 58.5 g as shown: $2Na + Cl_2 \rightarrow 2NaCl$.

In another example, one mole of carbon atoms (12 g of C) reacts completely with one mole of oxygen molecules (32 g of O_2) to form carbon dioxide in the reaction: $C + O_2 \rightarrow CO_2$, because one mole of carbon and one mole of molecular oxygen contain the same number of carbon atoms and oxygen molecules.

Determining Empirical Formulas

The empirical formula for a compound consists of the symbols of the constituent elements in their smallest whole-number ratio (e.g., H_2O or NaCl). The first step in determining the empirical formula of a compound is to convert the gram ratio of each element to a mole ratio. The mole ratio is then adjusted to its simplest whole-number ratio.

Example:

What percentage of nitrogen (N) and potassium (K) are in the fertilizer, potassium nitrate, KNO_3?

step 1: determine the molecular weight of each element in KNO_3:

K	=	1	x	39	=	39 g
N	=	1	x	14	=	14 g
O_3	=	3	x	16	=	48 g
					total	101 g

Step 2: Now determine the percentage of each element in KNO_3 by dividing the total weight of each element by the total formula weight of the compound. To express the value as a percent, multiply the results by 100.

$$K = \frac{39\ g}{101\ g} = 0.386 \text{ or } 38.6\%$$

$$N = \frac{14\ g}{101\ g} = 0.139 \text{ or } 13.9\%$$

$$O_3 = \frac{48\ g}{101\ g} = 0.475 \text{ or } 47.5\%$$

Therefore, pure KNO_3 contains 38% K, 14% N and 48% O. To check the results, add up the percentage of each element in the formula. This should equal 100 (38 + 14 + 48 = 100).

Parts Per Million

Another means of expressing exceedingly small concentrations is part per million (ppm). One expression of PPM is the concentration of one milligram (mg) of one substance distributed through one kilogram (kg) of another (**Table 1-3**). PPM also represents the concentration of one milligram of one substance dissolved throughout one liter of another (usually water).

Table 1-3. Common units in expressing concentrations.

Unit	wt/wt basis	wt/vol basis	vol/vol basis
Parts per million (ppm)	mg/kg or µg/g	mg/L or µg/ml	µL/ml
Parts per billion (ppb)	µg/kg or ng/g	µg/L or ng/ml	nL/L or pL/ml
Percent (%)	g/100 g	g/100 ml	ml/100 ml

Water Concentration Expressions

meq/L = ppm or mg/L ÷ equivalent weight (mg/meq)

ppm (mg/L) ÷ meq wt (mg/meq) = meq/L

meq/L = molecular weight ÷ valence no.

Ion	Multiply the following to convert mg/L to meq/L	Multiply the following to convert meq/L to mg/L
Na^{+}	0.043	23
Mg^{+2}	0.083	12
Ca^{+2}	0.05	20
Cl^{-1}	0.028	36
Sulfate (SO_4^{-2})	0.021	48
Bicarbonate (HCO_3^{-1})	0.016	61
Carbonate (CO_3^{-2})	0.033	30

Examples:

1. If atrazine concentration in a water sample is 0.1 g/L, how many ppm is this? (ppm = mg/L)

$$\frac{0.1g}{L} \times \frac{1,000\ mg}{1\ g} = 100 \text{ ppm (or mg/L)}$$

2. What is the concentration of Cu^{+2} ions, in parts per million, of a 750 ml aqueous solution containing 14.38 mg of Cu^{+2} ions? (ppm = mg/L).

$$750\ \cancel{ml} \times \frac{1\ L}{1,000\ \cancel{ml}} = 0.750\ L$$

ppm is normally expressed as mg/L, therefore:

$$\frac{14.38\ mg\ Cu^{+2}}{0.750\ L} = 19.2\ ppm\ Cu^{+2}$$

3. A soil sample indicates 0.001 ppm (mg/L) of hydrogen ions. What is the concentration (M/L) of hydrogen in the soil?

Concentration = moles/liter (M/L), therefore, 0.001 ppm must be converted to this.

$$0.001\ ppm = \frac{0.001\ mg}{L} \times \frac{1g}{1,000\ mg} \times \frac{1\ moles\ H^{+}}{1\ g\ H^{+}}$$

$$= 0.000001\ M/\text{Liter} = 1 \times 10^{-6} \text{ (this also equals pH 6)}$$

4. How much herbicide (formulated as 2 lb product per gallon) is needed to provide a 1 ppm mixture in a 2-acre pond with an average depth of 10 feet to control a certain weed?

Step 1: One needs to know the approximate gallons (or volume) of water in the pond. One means of estimating this is measuring the surface area of the pond and its average depth with the knowledge that 7.48 gallons can be held per cubic foot and pure water weighs 8.34 lb per gallon. Since the pond has 2 surface acres with an average depth of 10 feet, the following equations are used to determine volume:

$$\text{Surface area} = \text{ac} \times \frac{43{,}560\ \text{ft}^2}{\text{ac}}$$
$$= 2\ \text{ac} \times 43{,}560\ \text{ft}^2$$
$$= 87{,}120\ \text{ft}^2$$
$$\text{Volume} = \text{surface area} \times \text{average depth} \times \frac{7.48\ \text{gal}}{\text{ft}^3}$$
$$= 87{,}120\ \text{ft}^2 \times 10\ \text{ft} \times \frac{7.48\ \text{gal}}{\text{ft}^3}$$
$$= 6{,}516{,}576\ \text{gal}$$

step 2: To determine gallons of herbicide needed to obtain 1 ppm, the appropriate unit analysis conversion must be made:

$$\frac{6{,}516{,}576\ \text{gal water}}{\text{pond}} \times \frac{8.34\ \text{lb}}{\text{gal water}} \times \frac{\text{gal herbicide}}{2\ \text{lb ai}} \times \frac{1\ \text{part}}{1{,}000{,}000} = 27\ \text{gal}$$

Equivalent weights

Solution concentration can be expressed to allow chemically equivalent quantities of different solutes to be measured simply. **Equivalent weights**, as the name implies, are the amounts of reactants that are equivalent (have the same combining capacity) to each other in chemical reactions.

$$\text{equivalent weight (g)} = \frac{\text{molecular weight (g)}}{\text{oxidation number (or valence)}}$$

Example:

Suppose one wished to neutralize 100 negative charges (CEC, cmol_c/kg) in a soil sample using the least amount of material. Cations at your disposal include H^+, K^+, Na^+, Ca^{+2}, Mg^{+2}, and Al^{+3}. Which cation would provide the least weight needed to neutralize these 100 grams of negative charges and which one would require the most weight to neutralize this?

step 1: the equivalent weight of each cation first needs to be determined which will satisfy the charges of one negative charge:

$$\text{equivalent weight (g)} = \frac{\text{molecular weight (g)}}{\text{oxidation number (or valence)}}$$

$$1\ \text{eq}\ H^+ = \frac{1\text{g}}{1} = 1\ \text{g}\ H^+ \qquad 1\ \text{eq}\ Na^+ = \frac{23\ \text{g}}{1} = 23\ \text{g}\ Na^+$$

$$1\ \text{eq}\ K^+ = \frac{39\ \text{g}}{1} = 39\ \text{g}\ K^+ \qquad 1\ \text{eq}\ Ca^{+2} = \frac{40\ \text{g}}{2} = 20\ \text{g}\ Ca^{+2}$$

$$1\ \text{eq}\ Mg^{+2} = \frac{24\ \text{g}}{2} = 12\ \text{g}\ Mg^{+2} \qquad 1\ \text{eq}\ Al^{+3} = \frac{27\ \text{g}}{3} = 9\ \text{g}\ Al^{+3}$$

Since:

$$1\ \text{eq}\ H^+ = 1\ \text{eq}\ K^+ = 1\ \text{eq}\ Na^+ = 1\ \text{eq}\ Ca^{+2} = 1\ \text{eq}\ Mg^{+2} = 1\ \text{eq}\ Al^{+3}$$

On an equivalent basis:

$$1\ \text{g}\ H^+ = 39\ \text{g}\ K^+ = 23\ \text{g}\ Na^+ = 20\ \text{g}\ Ca^{+2} = 12\ \text{g}\ Mg^{+2} = 9\ \text{g}\ Al^{+3}$$

Step 2: Since 100 grams of negative charges need to be neutralized, these values are multiplied by 100. Therefore, 100 g H^+, 3900 g K^+, 2300 g Na^+, 2000 g Ca^{+2}, 1200 g Mg^{+2}, and 900 g Al^{+3} are needed to satisfy 100 negative charges. Hydrogen would require the least equivalent weight (100 g) to satisfy the 100 negative charges while potassium would require the most (3900 g).

Milliequivalent weight

In biological sciences the term **milliequivalent** is often used when describing nutrients and their levels in soils or water. In soil science, a milliequivalent is the amount of a cation (positive ion) that will displace 1 mg of hydrogen ions from the active soil solids, which are clay and humus. That amount, expressed in mg, is called the milliequivalent weight (meq-weight). Thus, one meq-weight is that amount (in mg) of a cation that will displace 1 meq-weight (1 mg) of H^+. When dealing with meq, 1 equivalent equals 1,000 meq and 1 equivalent/1,000 equals 1 meq.

Example:
What is 1 milliequivalent (meq) of calcium (Ca^{+2})?

step 1: the equivalence of calcium is determined:

$$1 \text{ equivalent } Ca^{+2} = \frac{40 \text{ g (atomic weight of } Ca^{+2})}{2 \text{ (valence charge of } Ca^{+2})} = 20 \text{ grams}$$

Step 2: this has to be converted to meq: therefore, if 1 equivalent Ca^{+2} = 20 grams; then this is divided by 1,000 to obtain meq. Thus 1 meq of Ca^{+2} = 0.020g = 20 mg. This can be rewritten as:

$$20 \text{ g } Ca^{+2} \times \frac{1 \text{ eq}}{1000 \text{ meq}} \times \frac{1000 \text{ mg}}{1 \text{ g}} = 20 \text{ mg}$$

Example:
Determine the amount of Ca^{+2} in ppm and lb nutrient/acre and nutrient/1,000 sq.ft. for 1 meq/100 g soil (remember, ppm can be expressed as 1 g per 1,000,000 g and 1 acre furrow slice weighs ~ 2 million lbs).

$$\frac{1 \text{ meq } Ca^{+2}}{100 \text{ g soil}} \times \frac{40 \text{ g (atomic weight of } Ca^{+2})}{2 \text{ (valence charge of } Ca^{+2})} \times \frac{10{,}000}{10{,}000} = \frac{200{,}000 \text{ mg } Ca^{+2}}{1{,}000{,}000 \text{ g soil}}$$

Since 1,000 mg = 1 g

$$\frac{200{,}000 \text{ mg } Ca^{+2}}{1{,}000{,}000 \text{ g soil}} \times \frac{1 \text{ g}}{1{,}000 \text{ mg}} = \frac{200 \text{ g}}{1{,}000{,}000 \text{ g soil}} = \textbf{200 ppm}$$

$$\frac{1 \text{ meq } Ca^{+2}}{100 \text{ g soil}} \times \frac{40 \text{ g (atomic weight of } Ca^{+2})}{2 \text{ (valence charge of } Ca^{+2})} \times \frac{1 \text{ eq}}{1{,}000 \text{ meq}} \times \frac{2{,}000{,}000 \text{ lb}}{\text{AFS}}$$

$$= \frac{400 \text{ lb } Ca^{+2}}{\text{Acre furrow slice}} \times \frac{1 \text{ acre}}{43.56 \ (1000^{th})} = \frac{9.2 \text{ lb } Ca^{+2}}{1{,}000 \text{ sq.ft.}}$$

or, Since ppm x 2 = lb/acre, $\frac{400 \text{ lb } Ca^{+2}/\text{acre}}{2} = \textbf{200 ppm}$

Practice Problems (*answers*)

1. What is an *atom*? (*the smallest particle that can exist as an element*).

2. What is a *molecule*? (*the smallest particle of a substance that retains properties of that substance*).

3. What is an *element*? (*a substance that cannot be broken into a simpler substance by chemical change*).

4. What is the structure and location of the proton, electron, and neutron in respect to the nucleus of an atom? (*the nucleus of an atom is composed of protons and neutrons and occupies a very small part of the volume of an atom. Electrons exist outside the nucleus and occupy most of the volume of atoms*).

5. Find the number of protons, electrons, and neutrons of an atom with an atomic number of 6 and a mass number of 14.
   a. *Number of protons = atomic number = 6.*
   b. *Number of neutrons = mass number - atomic number = (14 - 6) = 8.*
   c. *Number of electrons = number of protons = 6.*

6. What is meant by the term *mole*? (*chemical unit to "count" atoms and molecules. There are 6.02 x 10^{23} particles in a mole, which is also known as Avogadro's number*).

7. What is the percent composition of H and O in H_2O? (*11.1% H, 88.9% O*).

8. What is the percent composition of $Ca(NO_3)_2$? (*24.5% Ca; 17.1% N; 58.5% O*).

9. What is the percent composition of glucose ($C_6H_{12}O_6$)? (*40% C; 6.71% H; 53.29% O*).

10. How many kg of iron can be removed from 639 kg of Fe_2O_3? (Fe_2O_3 *is 70% Fe, therefore, 447 kg Fe*).

11. What is meant by *molecular weight*? (*the weight, in grams, of one mole [6.02 x* 10^{23} *molecules] of a compound*).

12. Calculate the formula weights of:
    a. KNO_3 (potassium nitrate) (*101.8 g*)
    b. $CO(NH_2)_2$ (urea) (*60.04 g*)
    c. NaOCl (bleach) (*74.44 g*)
    d. K_2SO_4 (potassium sulfate) (*174.3 g*)

13. What is the equivalent weight of KOH? (*56.1 g*).

14. How many grams are in 1 equivalent of each of the following?
    a. $Ca(NO_3)_2$ (*82 g*)
    b. Zn (*32.7 g*)
    c. HCO_3^- (*61.0 g*)
    d. KCl (*74.6 g*)
    e. $Al_2(SO_4)_3$ (*57.0 g*)

15. How many equivalents are in 20.5 g of sulfurous acid, H_2SO_3? (*0.50 equivalents*).

16. What is the equivalent weight of HSO_4^-? (*97 g*).

17. Convert 97.5 mg of K^+ to milliequivalent weight. (*2.5 meq* K^+).

18. A soil sample from a coastal golf course fairway was analyzed and found to have a sodium (Na) concentration of 8,000 ppm (mg/kg), how many meq Na^+/100 g does this soil contain? (*34.8 meq/100 g. This would be considered very high and only the most salt tolerant turfgrasses would be expected to survive*).

UNIT 2

TURFGRASS ANATOMY, MORPHOLOGY, AND IDENTIFICATION

Objectives:

1. Familiarize students on the taxonomic means plants are classified and what morphological characteristics these are based.
2. Allow the student sufficient practice on identifying turfgrasses and other plants based on morphological characteristics.

Assigned Reading: Chapter 1, *Golf Turf Management*.

GRASSES

Grasses are the most important agricultural plants in the world. In addition to providing a wide variety of food, they help stabilize various environments; provide the major plants used as turf in lawns, parks, sports fields, and golf courses; and furnish a large group of ornamental grasses for horticultural uses.

Living organisms are classified based on shared characteristics and natural relationships. The grass family, *Poaceae* (formerly known as *Gramineae*), includes six subfamilies and about 600 genera with more than 7,500 species. Within some species, there are further subdivisions called subspecies, varieties, or cultivars.

Living organisms are identified by a Latin binomial classification system. The first name is the Latin description for the genus while the second name represents the species. The taxonomic authority may be added to the Latin binomial following the species designation to indicate who first identified the species. For example, perennial ryegrass has the Latin binomial (also called the scientific name) of *Lolium perenne* L., with the L. serving as an abbreviation representing Carl Linnaeus, a botanist who first described this species.

Other variations of the descripting authors occur. For example, bermudagrass has the Latin binomial of *Cynodon dactylon* [L.] Pers., which indicates Linnaeus (or L.) first described the species but in a different genus or as a separate species or at a different rank. Later, another author, Christiaan Persoon (abbreviated as Pers.), moved it to the *Cynodon* genus and is considered the primary author while Linnaeus, in brackets, is the secondary author.

Other rules apply with multiple authorities. For example, with the Latin name of mascarenegrass, (*Zoysia tenuifolia* Willd. ex Trin.), the term "ex" represents Carl Ludwig Willdenow (abbreviated Willd.) first proposed the name but Carl Bernhard von Trinius (abbreviated Trin.) later provided the recognized valid description. Further subdivisions are necessary when important differences exist within a species but not to the extent to warrant separation into a different species. **Cultivars,** a contrived word meaning CULTIvated VARiety (abbreviated as cv.), represent a subdivision of cultivated plants and subspecies (ssp.). Variety (var.) and form (f.) describe further subdivisions in wild populations of plants. For example, the Latin designation for the Rebel cultivar of tall fescue is *Lolium arundinaceum* (Schreb.) Darbysh. cv. Rebel while the subdivision of the perennial (creeping) biotype of the wild population of annual bluegrass is *Poa annua* L. ssp. *reptans* or *Poa annual* L. var. *reptans.*

Interspecific hybrids are designated by the names of the two parent species included in the Latin name separated by an "X." For example, Emerald zoysiagrass is referred to as *Zoysia japonica* X *Z. tenuifolia* since it is a selected hybrid between *Zoysia japonica* and *Zoysia tenuifolia.*

PLANT CHARACTERISTICS

Flowering plants, (also called **angiosperms**) are divided into two subclasses, named for the number of **cotyledons,** or food storage organs, possessed by their seed embryo (**Figure 2-1**). **Dicotyledons,** also known as **dicots,** have two storage organs, while **monocotyledons,** also known as **monocots,** have one.

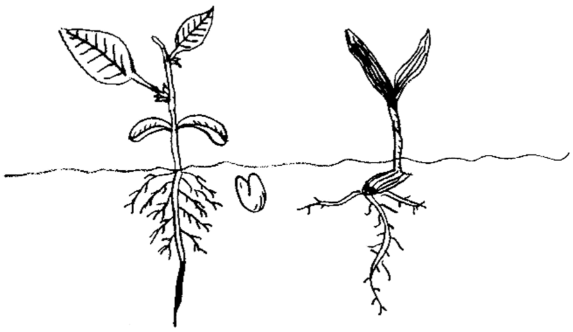

Figure 2-1. Germinating dicotyledons (or dicots, left), compared to monocotyledons (or monocots, right). Dicots have two storage organs while monocots have one. Monocots typically have long, two-ranked, thin leaves with parallel veins while dicots have leaves of various shapes, often wider than long, with a vein network. They also have showy flowers (not shown). Monocots' leaves are usually attached directly to the stem while dicot leaves usually have short stalks called petioles.

Crowns

Crowns are, arguably, the most important organ in grasses. The crown is the primary **meristematic tissue** or growth zone for cell division and enlargement of established plants and is located at the base of the plant near the soil surface where leaves, roots, and stems join (**Figure 2-2**). All new leaf, root, and stem growth originates at the crown. The crown is the primary meristematic tissue and if it is not damaged, the plant can recover from environmental stresses, dormancy, excessive defoliation, and pest damage.

Leaves

The organs of grasses are the shoots (stems plus leaves, referred to as primary shoot) and roots. As the plant develops from germinating seed, the shoot (or culm) becomes apparent. At this stage, the shoot consists of a series of concentric leaves, with the oldest on the outside and younger ones forming in the center, pushing upwards until they emerge.

Leaves consist of a sheath, blade, and ligule. The **sheath** is the lower portion of the leaf which is wrapped around the shoot above the node and from which the leaf bud emerges (**Figure 2-2**). **Blades** (also called **lamina**) are parallel veined and typically flat, long, and narrow. Leaves on mature plants are borne on the **stem,** alternately in two rows, one at each node. A large vein, the **midrib,** extends through the middle of the blade and lesser veins run parallel on each side of it. In some grasses, the edge of the blade feels rough when rubbed. The blade may have hairs on either the upper or lower surface or both.

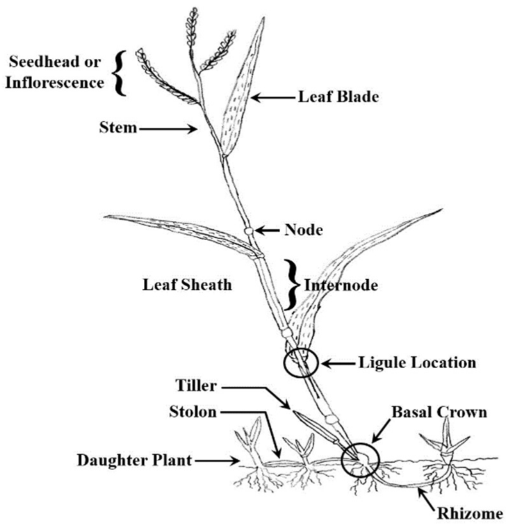

Figure 2-2. The primary structures of a grass plant.

Vernation is the arrangement of the youngest leaf protruding from the sheath of an older leaf in the bud shoot and is either **rolled** or **folded** (**Figure 2-3**). Turfgrasses with rolled vernation include annual ryegrass, buffalograss, creeping bentgrass, and zoysiagrass. Bermudagrass, perennial ryegrass, bluegrass, and St. Augustinegrass have folded vernation.

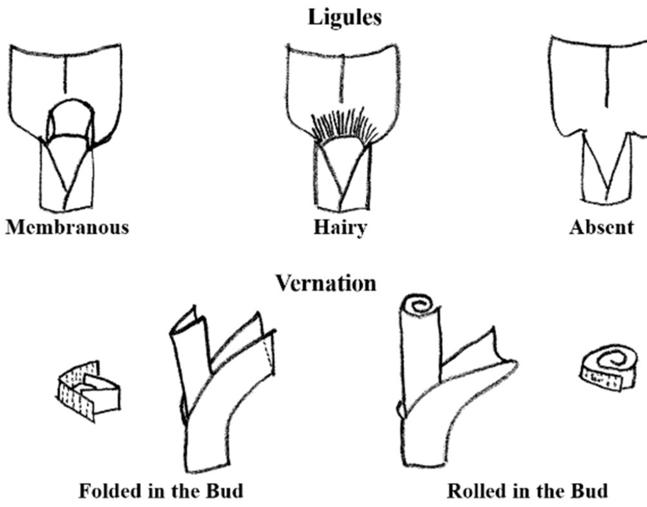

Figure 2-3. Ligule types (top) and vernation of grasses.

Leaf tip shapes also aid in separating and identifying certain turfgrasses. **Pointed** leaf tips are the most common for turfgrasses (**Figure 2-4**). Examples include bahiagrass, ryegrass, fescue, zoysiagrass, and bermudagrass. **Blunted** or **rounded** leaf tips are associated with carpetgrass, centipedegrass, and St. Augustinegrass. **Boat-shaped** leaf tips are associated with the bluegrasses and centipedegrass.

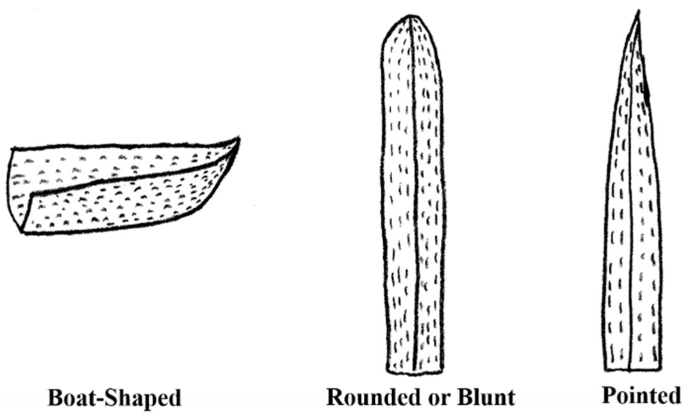

Figure 2-4. Three common leaf blade tips associated with turfgrasses.

The collar region is where the leaf blade and sheath join and contains the **collar, auricles,** and **ligule.** The ligule, one of the most important diagnostic features of grasses, is a projection or extension from the top of the leaf sheath where the leaf sheath and blade join. It can vary considerably in its texture, size, and shape (**Figure 2-3**). Most commonly, the ligule is either a membranous structure, a fringe of hairs, or is absent. Auricles are appendages extending from the edge of the leaf where the blade and sheath meet. Auricles are claw-like, short, or absent. For example, annual ryegrass has prominent, claw-like auricles. The development of these appendages marks the end of elongation growth, at which point the leaf has reached its final length. Meanwhile, the next leaf is moving up inside the previous leaf's sheath.

Stems

Stems are the basic structural feature from which turfgrasses develop and are the connecting structures between leaves and roots. Stems consist of **internodes** spaced between nodes with attached leaves. Grasses are composed of three different types of stems: **crowns**, **flowering culm** (or **seedhead**), and **lateral stems** (rhizomes, stolons, and tillers). Most grasses have soft, succulent growth and are referred to as herbaceous (or non-woody). The jointed stem of a grass is distinctly divided into a series of nodes and internodes and is terminated by an **apical bud.** Internodes are usually cylindrical and hollow, while nodes are solid. Successive leaves are initiated by the swollen meristematic stem apex at the node, which in most species remains short during vegetative development so leaves arise close together. Since they originate from the same point, the number of nodes and internodes equals the number of leaves.

Alternately appearing on either side of the crown is a series of axillary buds which give rise to lateral stems, such as tillers, rhizomes, and stolons. Tillers, or primary lateral shoots, develop when lateral stems grow up within the leaf lying under the node. As the leaf sheath develops from the crown, it appears to wrap completely around the crown, including the axillary buds. Therefore, developing axillary buds either must grow through or within the leaf sheath. When these are retained within the surrounding leaf sheath and grow upright, tillering is referred to as **intravaginal,** and produces a tufted or bunch-type (non-creeping) growth habit. Ryegrass and fescue have bunch-type growth habits, spread very slowly, and tend to grow in clumps or bunches.

Extravaginal tillering (or shoot development) occurs where the lateral stem elongates and penetrates through the side of the surrounding leaf sheath to produce a spreading or creeping growth habit. Extravaginal tillers form either rhizomes (belowground stems) or stolons (aboveground stems which possess fully developed leaves) and are referred to as **secondary lateral shoots.**

Roots

Roots anchor plants to soil and take up water and nutrients. Roots also function in food storage and are the primary source of certain plant growth hormones, such as gibberellins and cytokinins.

Turfgrasses have fibrous, branched root systems, mostly located in the upper foot of soil. The **primary** (also called **seminal**) grass roots arise from the root tissues of seed embryo and generally persist for only a short time (one to two months) after germination. The primary root is the first structure to emerge from the embryo. The **secondary** (also called adventitious) roots arise two to three weeks after germination at the lower nodes just below the internodal intercalary meristem of young stems and comprise the major part of the permanent root system. The root system is progressively replaced by adventitious roots which arise at nodes of creeping stems (stolons), lower plant crowns, and from older roots.

Inflorescence

The seedhead or **inflorescence** of a turfgrass is the reproductive organ where seeds are formed. Unlike other organs, inflorescences are not present throughout the life of the plant. They originate when a grass plant enters the reproductive stage and an elongated stem from the apical meristem of the crown is produced. Flowers and seed appear at the top of this elongated stem, called the flowering culm.

Several spikelet cluster types exist, including **raceme, spike,** and **panicle** (**Figure 2-5**). The simplest is the raceme where spikelets are borne on individual stalks (or **pedicels**) on an unbranched main axis. St. Augustinegrass, bahiagrass, zoysiagrass, and centipedegrass have raceme inflorescences. The spike differs from the raceme, since spike has sessiled (without a stalk or pedicel) spikelets on the main axis while racemes have simple stalked spikelets. Wheatgrass and ryegrass have the spike form of inflorescence (**Tables 2-1 and 2-2**).

The panicle is the most common type of grass inflorescence. In this case, the spikelets are similar to the raceme because they are attached to the main axis (or rachis) but are in a branched inflorescence. Racemes have simple stalked spikelets. Some panicles are tightly branched while some are multi-branched, resembling the limbs and leaves of trees. Most turfgrass inflorescence have the panicle arrangement including bluegrass, creeping bentgrass, and tall fescue.

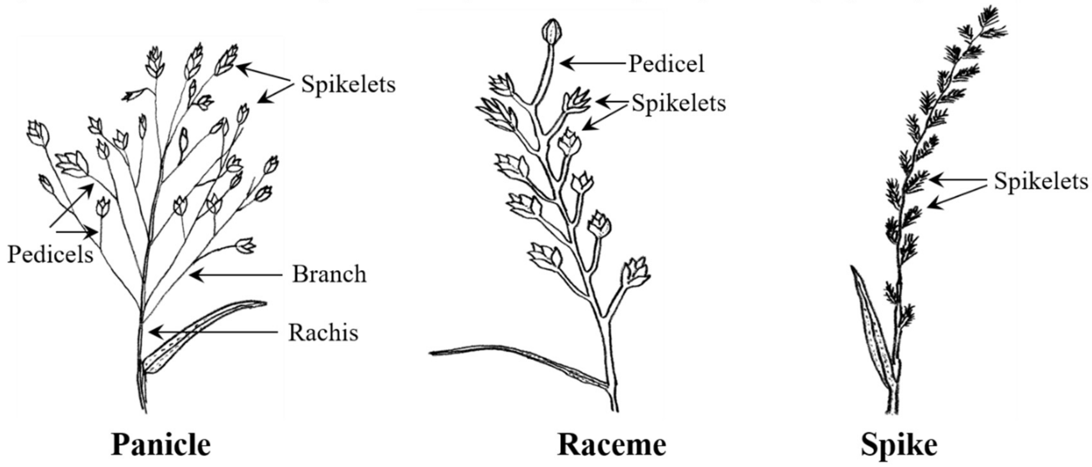

Figure 2-5. Three types of seedheads (or inflorences) for turfgrasses based on the arrangement of the spikelets include panicle (left), raceme (center), and spike (right).

Table 2-1. Distinguishing morphological characteristics of warm-season (or C_4) turfgrasses.

Turfgrass	Leaf texture (width, mm)	Lateral shoot type	Leaf vernation	Ligule type (length, mm)	Auricles	Leaf tip	Inflorescence	Additional characteristic(s)
Bahiagrass *Paspalum notatum* Flugge.	coarse (4–8)	very short stolons, rhizomes	folded or rolled	membrane (1)	absent	pointed	branched spikelike 2, rarely 3 branched racemes	Tall, 2- to 3-spiked, V-shaped seedheads. Wide leaf blade with hairy margins, Reddish-purple stem base. Tough, drought and nematode resistant, low maintenance.
Bermudagrass *Cynodon dactylon* (L.) Pers.	fine to coarse (1–3)	stolons, rhizomes	folded	hair (1–3)	absent	pointed	4 or 5 digitate spikelike racemes	Fine leaf texture and dense stand density. Collar narrow, covered with hairs. Some hairs on leaf surface. Very poor shade tolerance.
Blue Grama *Bouteloua gracilis* (HBK) Lag. ex Steud.	fine to medium (1–2)	rhizomes	rolled	hair (0.1–0.5)	absent	pointed	spike, spreading at maturity	Blue-green color from hairy leaves. Adapted to warmer regions of arid transition zone. Forms low-maintenance turf.
Buffalograss *Buchloe dactyloides* (Nutt.) Engelm	fine to medium (1–3)	stolons	rolled	hair (0.5–1)	absent	pointed	separate male & female flowers	Collars hairy. Blue-gray color due to leaf pubescence. Drought resistant. Very poor shade tolerance. Male flowers appear as curved branches at main stem top, female flowers are hard burs just above leaf sheath.
Carpetgrass *Axonopus affinis* Chase	medium to coarse (4–8)	stolons	folded	fringe of hairs (1)	absent	rounded (blunt)	raceme, usually 3	Similar to St. Augustinegrass except lighter-green color leaves which twist and have "waves" along margins. Seedheads resembling "crabgrass seedheads" with 2 to 5 spikes at apex. Tolerates wet conditions. Collar narrow, continuous (indistinct).
Centipedegrass *Eremochloa ophiuroides* (Monro.) Hack	medium (3–5)	stolons	folded	short membrane (0.5) with hairs across the top	absent	rounded (blunt)	single spikelike solitary racemes	Natural yellow-green color, medium textured leaves with hairs along edges. Collar broad, much constricted, hairy. Used as low-maintenance grass. Grows best at slightly acidic (5.0 to 6.0) soil pH.
Kikuyugrass *Pennisetum clandestinum* Hochst ex. Chiov.	medium (4–5)	rhizomes & stolons	folded	hair (2)	absent	pointed	2 to 4 spikelets	Very tough grass with hairy leaves. Poor shade tolerance. Usually considered a weed. Use cautiously.

Turfgrass	Leaf texture (width, mm)	Lateral shoot type	Leaf vernation	Ligule type (length, mm)	Auricles	Leaf tip	Inflorescence	Additional characteristic(s)
Seashore Paspalum *Paspalum vaginatum* Swartz	medium to coarse (3–8)	stolons, rhizomes	folded or rolled	membrane (0.8–1.2)	absent	pointed	spikelike racemes	Good salt but poor cold tolerance. Blue-green color. Good for brackish water areas.
St. Augustinegrass *Stenotaphrum secundatum* (Walt.) Kuntze.	coarse (4–10)	stolons	folded	hair (0.3)	absent	rounded, boat-shaped	single spikelike racemes	Long, thick stolons and wide leaf blades. Cold tolerance poor to fair. Good shade and salt tolerance.
Zoysiagrass: Manilagrass *Zoysia matrella* (L.) Merr. **Meyer** *Z. japonica* Steud. **Mascarenegrass** *Z. matrella* (L.) Merr. var. *tenuifolia* (Willd. ex Thiele) Sasaki	fine (2–3) to coarse (4–6)	stolons, rhizomes	rolled	hair (0.2)	absent	pointed	spikelike terminal racemes	Stiff to the touch. Collar covered with long hairs; hairy on leaf surface. Fine leaf texture, dark green, dense turf. Has good shade tolerance (cultivar dependent).

Table 2-2. Distinguishing morphological characteristics of cool-season (or C_3) turfgrasses.

Turfgrass	Leaf texture (width, mm)	Lateral shoot type	Leaf vernation	Ligule type (length, mm)	Auricles	Leaf tip	Inflorescence	Additional characteristic(s)
Annual bluegrass *Poa annua* L.	fine (0.5–2.2)	tillers (annual biotype), short stolons (perennial biotype)	folded	membrane (1.5–2)	absent	boat-shaped	panicle	Pale-green color; dull on underleaf; prolific seedhead producer under all mowing heights. Transparent, parallel "light" lines on either side of the midrib. Often a major weed.
Annual ryegrass *Lolium multiflorum* Lam.	medium to coarse (3–7)	tillers	rolled	membrane (1–2)	long, narrow, claw-like	pointed	spike	Glossy on underleaf; red stem base. Lighter-green color and coarser leaf texture than perennial ryegrass. Seed (or spikelets) awned.
Colonial bentgrass *Agrostis tenuis* Sibth.	fine (1–3)	tillers, short stolons	rolled	membrane (0.4–1.2)	absent	pointed	panicle	Tufted (patch-like) growth habit. Rhizomes and stolons are either absent or short.
Creeping bentgrass *Agrostis palustris* subsp. *stolonifera* L.	fine (1–3)	stolons	rolled	membrane (1–3)	absent	pointed	panicle	Leaf blades rough along the edges.

Turfgrass	Leaf texture (width, mm)	Lateral shoot type	Leaf vernation	Ligule type (length, mm)	Auricles	Leaf tip	Inflorescence	Additional characteristic(s)
Crested wheatgrass *Agropyron cristatum* (L.) Gaertn.	medium (2–5)	tillers	rolled	membrane (0.5–1.5)	claw-like	pointed	spike	Prominent veins above and midrib below. Natural blue-green color. Adapted to cooler regions of arid transition zone.
Fine fescue: **Red fescue** *Festuca rubra* L. **Chewings fescue** *F. rubra* ssp. *communtata* Gaud.	fine (0.5–2)	rhizomes, tillers	folded	membrane (0.2–0.5)	absent	pointed	panicle	Very fine, needlelike, leaf texture. Red fescue produces rhizomes while chewings fescue does not. Sheep, creeping, meadow, and hard fescues are additional fine fescues.
Kentucky bluegrass *Poa pratensis* L.	medium (2–4)	rhizomes, tillers	folded	membrane (0.5–2)	absent	boat-shaped	panicle	Transparent, parallel "light" lines on either side of the midrib.
Orchardgrass *Dactylis glomerata* L.	coarse (2–10)	tillers	folded	membrane very tall (3.5–7)	absent	pointed	panicle	Coarse leaf texture; pale blue-green color. Prominent leaf midrib. Often a seed contaminant in tall fescue.
Perennial ryegrass *Lolium perenne* L.	medium (2–5)	tillers	folded	membrane (0.5–1.5)	short, non-clasping	pointed	spike	Prominent veins and leaf midrib. Very glossy on the back of leaves; red stem base. Seed (or spikelets) unawned.
Roughstalk bluegrass *Poa trivialis* L.	fine (1–6)	short stolons	folded	membrane (2–6)	absent	boat-shaped	panicle	Short creeping stolons. Light-green leaf color; glossy on underleaf. "Boat-shaped" leaf tips. Leaf margins rough.
Tall fescue *Lolium arundinaceum* (Schreb.) Darbysh.	coarse (5–10)	tillers, short rhizomes	rolled	membrane (0.2–0.8)	rudimentary to absent	pointed	panicle	Leaf blade rough along edges, bunch-type growth, prominent midrib and veins; red stem base.
Velvet bentgrass *Agrostis canina* L.	fine (<1)	short stolons	rolled	membrane (0.4–0.8)	absent	pointed	panicle	Very fine leaf texture. Leaf blades rough along edges.

Name:______________________________ **Date:________________________**

Lab Report on Results and Discussion (due next week)

For a specified grass, locate, sketch, and label each of the following plant structures, noting their size, color, and surface characteristics such as pubescence, rough edges, etc.

Seedhead

Stem

Shoot

Tiller

Rhizome

Stolon

Node and Internode

Roots and Root Hairs

Leaf Blade including Tip

Leaf Sheath

Auricles

Collar

Ligule

Vernation

Crown

UNIT 3

SOIL CHEMICAL PROPERTIES

Objectives:
1. Review the importance of equivalence and milliequivalent units in soil science,
2. Examine the importance and means of calculating soil cation exchange capacity (CEC),
3. Examine the importance and means of calculating percent base saturation,
4. Examine the importance and means of measuring soil acidity.

Assigned Reading: Chapter 3, *Golf Turf Management* plus complete Unit 1, Basic Math & Chemistry Autotutorial Lab.

SOIL CHEMICAL PROPERTIES

Equivalents

Equivalents indicates how much of one cation is required to replace another when dealing with charge. For example, if two H^+ ions (each having a single charge) are bound to a clay particle, then one Ca^{2+} (with a 2+ charge) can replace both H^+ ions on the exchange site. We often need to determine how many grams of one cation are needed to replace another cation. Equivalent weights need to be understood to calculate this type of reaction. Equivalent weights are determined by dividing an element's atomic weight by its valence number. **Table 3-1** displays equivalent weights for some common soil cations.

Table 3-1. Atomic weights, valence numbers, and equivalent weights of major soil cations.

Element	Atomic Weight	Valence	Equivalent Weight
H^+	1	+1	1
K^+	39	+1	39
Na^+	23	+1	23
NH_4^+	18	+1	18
Ca^{2+}	40	+2	20
Mg^{2+}	24	+2	12
Al^{3+}	27	+3	9

Given the equivalent exchange information in **Table 3-1**, we can state that all of the following are equivalent in soil exchange reactions:
$1g\ H^+ = 39g\ K^+ = 23g\ Na^+ = 18g\ NH_4^+ = 20g\ Ca^{2+} = 12g\ Mg^{2+} = 9g\ Al^{3+}$

Example:
Determine how many pounds of Ca are needed to completely replace 1,500 lb of Na in a soil:
step 1: First, determine the equivalents of sodium (Na^+) based on 1,500 lb Na^+.

$$1{,}500 \text{ lb Na} \times \frac{454\text{g Na}}{1 \text{ lb Na}} \times \frac{1\text{eq Na}}{23\text{g Na}} = 29{,}608 \text{ eq Na}$$

Now, we know how many equivalents of Ca^{2+} we need to replace 1,500 lb of Na^+: 29,608 equivalents of Na^+ can be replaced with 29,608 equivalents of Ca^{2+}.

step 2: Calculate how many pounds of Ca^{2+} are equal to 29,608 eq of Ca^{2+}:

$$29{,}608 \text{ eq Ca} \times \frac{20\text{g Ca}}{1 \text{ eq Ca}} \times \frac{1 \text{ lb Ca}}{454\text{g Ca}} = 1{,}304 \text{ lb Ca}$$

Therefore, it would take 1,304 lb of Ca^{2+} to completely replace 1,500 lb of Na^+.