Agronomy 354
Chemistry Review

A few chemical principles are important for you to fully understand soil fertility and plant growth/nutrition. You should know the name, chemical symbol, valence, and ion name of these elements.

Macronutrients

Element	Symbol	Ionic form	Atomic/Mol wt.	Valence	Ion name	Example
Nitrogen	N	NO_3^-	62	-1	nitrate	KNO_3
		NH_4^+	18	+1	ammonium	NH_4Cl
Phosphorus	P	HPO_4^{2-}	96	-2	hydrogen phosphate	$CaHPO_4$
		$H_2PO_4^-$	97	-1	dihydrogen phosphate	$Ca(H_2PO_4)_2$
Potassium	K	K^+	39	+1	potassium	KCl
Calcium	Ca	Ca^{2+}	40	+2	calcium	$CaCl_2$
Magnesium	Mg	Mg^{2+}	24	+2	magnesium	$MgCl_2$
Sulfur	S	SO_4^{2-}	96	-2	sulfate	$CaSO_4$
Hydrogen	H	H^+	1	+1	hydrogen (proton)	H_2O
Oxygen	O	O^{2-}	16	-2	oxygen	H_2O
Carbon	C	CO_3^{2-}	12	-2	carbonate	$CaCO_3$

Micronutrients

Element	Symbol	Ionic form	Atomic/Mol wt.	Valence	Ion name	Example
Iron	Fe	Fe^{2+}	56	+2	ferrous	FeO
		Fe^{3+}	56	+3	ferric	Fe_2O_3
Copper	Cu	Cu^{2+}	63.5	+2	cupric	CuO
Manganese	Mn	Mn^{2+}	55	+2	manganous	MnO
Nickel	Ni	Ni^{2+}	59	+2	nickel	$NiSO_4$
Zinc	Zn	Zn^{2+}	65	+2	zinc	ZnO
Boron	B	BO_3^{3-}	59	-3	borate	H_3BO_3
Molybdenum	Mo	MoO_4^{2-}	160	-2	molybdate	Na_2MoO_4
Chlorine	Cl	Cl^-	35.5	-1	chloride	NaCl

(over)

Terminology

Atoms of chemical elements are the fundamental units of all matter. **Ions** are atoms that carry an electrical charge. Positively charged ions are call **cations**, and negatively charged ions are called **anions**. The amount of this charge is determined by the number of electrons that an element has gained or lost, which indicates combining ability and is called **valence**. With two valence states, "ic" denotes the higher state (ferric, Fe^{3+}) and "ous" the lower state (ferrous, Fe^{2+}).

Atomic weight is the relative weight of atoms of various elements (C is 12.0000 g).

Mole is the amount of any substance containing 6.023×10^{23} elementary units (Avogadro's number). Units may be atoms, molecules, ions, electrons, photons, etc. For example, one mole of nitrate weighs 62 g and contains 6.023×10^{23} NO_3^- molecules. One mole of potassium weighs 39 g and contains 6.023×10^{23} K atoms. One mole of potassium ions weighs 39 g and contains 6.023×10^{23} positive charges (the weight of the lost electrons is quite small). One mole of calcium ions weighs 40 g and contains 12.046×10^{23} positive charges (each ion has two positive charges).

> Note: **meq of charge/100g = cmol of charge/kg**
> (The numbers are the same--both numerator and denominator vary by a factor of 10.)

Equivalent weight is the weight of a substance that contains 6.023×10^{23} charges.
Soil cation exchange capacity is normally expressed as milliequivalents (meq) per 100 g soil (or cmol per kg soil). This expresses the amount of charge present. One equivalent of charge (mole of charge) is equal to 6.023×10^{23} charges, and a milliequivalent is equal to 1/1000 of an equivalent or 6.023×10^{20} charges (when dividing 6.023×10^{23} by 1000, one substrates the exponents--10^{23}-10^{3}). Therefore, a soil that has 30 meq/100 g of cation exchange capacity has 180×10^{20} or 1.8×10^{22} negative exchange sites to which positively charged ions could be attracted (30 times $6.023 \times 10^{20} = 180 \times 10^{20}$).

Examples:

One mole of potassium ions weighs 39 g and has 6.023×10^{23} ions, each with a single charge, or represents 6.023×10^{23} charges. The equivalent weight of K is 39 g. One milliequivalent (1/1000 of an equivalent) of potassium ions weighs 39 mg (39 g/1000), and represents 6.023×10^{20} charges. Therefore, the milliequivalent weight of K is 39 mg.

One mole of calcium weighs 40 g and has 6.023×10^{23} calcium ions, each with two positive charges. Therefore, the equivalent weight of calcium ions is 40/2 or 20 g, which represents 6.023×10^{23} charges. Thus, the milliequivalent weight of calcium ions is 20 mg, which represents 6.023×10^{20} charges.

One milliequivalent of potassium ions (39 mg) will occupy exactly the same number of negative exchange sites in soil as one milliequivalent of calcium ions (20 mg); i.e, 6.023×10^{20} sites.

In general:

$$\textbf{Milliequivalent weight} = \frac{\textbf{atomic weight (in milligram)}}{\textbf{valance}}$$

Verify:

(1) If a soil holds 400 mg per 100 g of Ca ions on cation exchange sites, the soil has a CEC of 20 meq/100 g.
(2) If a soil has a CEC of 15 meq/100 g, it could hold 585 mg of K^+, or 180 mg of Mg^{2+}, or 0.345 g of Na^+.