



Centurion
UNIVERSITY

*Shaping Lives...
Empowering Communities...*

ASAC 1101 : FUNDAMENTALS OF SOIL SCIENCE (2+1)

Level : B.Sc (Ag), I semester

Dr. PEDDA GHOUSE PEERA S.K.

SOIL SCIENCE AND AGRICULTURAL CHEMISTRY

**M.S.SWAMINATHAN SCHOOL OF AGRICULTURE,CUTM,
PARLAKHEMUNDI**

Topic

**Origin of charge in organic and inorganic colloids –
Negative and positive charges-Differences between
organic and inorganic soil colloids**

Concepts Covered:

- Constant charges in colloids**
- Variable charges in colloids**
- Adsorption of cations and anions to colloidal surface**

Types of charges

Two types of charges arise in soil colloids

- **Constant or permanent charges**

 - isomorphous substitution occurs

- **Dependent or variable charges**

 - charge depends on solution pH

Constant charges

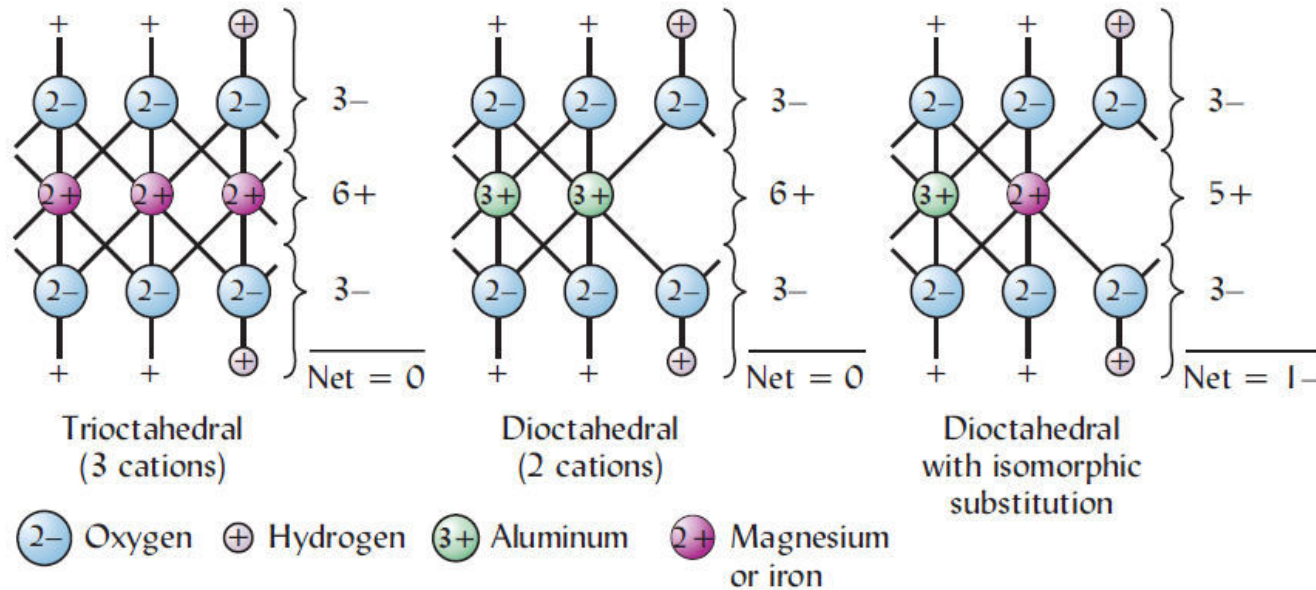
- Constant charges arise due to isomorphous substitution
- Not dependent on pH
- Isomorphous substitution – replacement of a cation by another cation of similar size
- Depends on type and abundance of cations
- Common in 2:1 clays

Constant charges

Negative charge

- ❑ Negative charge arises when a lower charged cation replaces higher charged cation
- ❑ Example : replacement of Al^{3+} with Mg^{2+} in octahedral sheets
replacement of Si^{4+} with Al^{3+} in tetrahedral sheets (fine grained mica)

Constant charges – negative charge



- Al³⁺ replaced by Mg²⁺
- Occurs in aluminium dominated dioctahedral sheets of smectites, vermiculites and chlorites

Constant charges

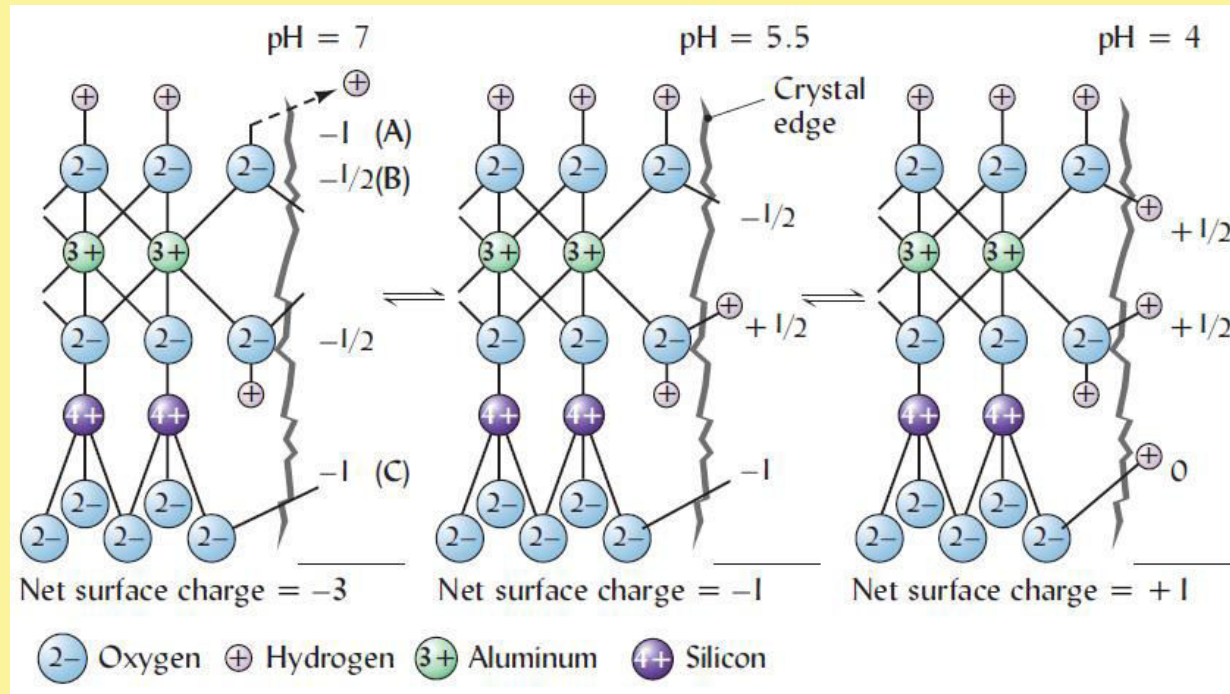
Positive charge

- ❑ Positive charge arises when a higher charged cation replaces lower charged one
- ❑ Example: When Al^{3+} replaces one Mg^{2+} in trioctahedral sheets
- ❑ Common in trioctahedral hydroxide sheet in chlorites

Variable charges

- Mainly found in 1:1 clays like kaolinite and humus (because exchange occurs in external surface only)
- May give rise to both positive and negative charge
- Charge depends on pH of soil solution

Development of pH-dependent charge in kaolinite

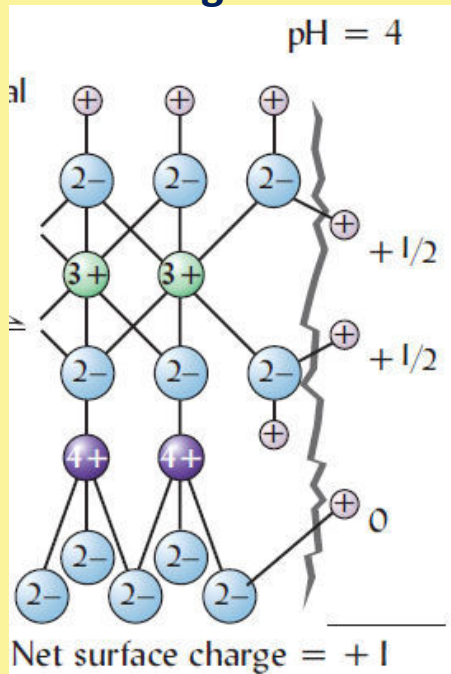


pH decreases from left to right

(A) One (-1) charge from octahedral oxygen that has lost its H⁺ ion by dissociation (the H broke away from the surface hydroxyl group and escaped into the soil solution). Note that such dissociation can generate negative charges all along the surface hydroxyl plane, not just at a broken edge. (B) One half (-1/2) charge from each octahedral oxygen that would normally be sharing its electrons with a second aluminum. (C) One (-1) charge from a tetrahedral oxygen atom that would normally be balanced

Variable charge

Positive charge



❑ Occurs under moderate to extreme acidic conditions

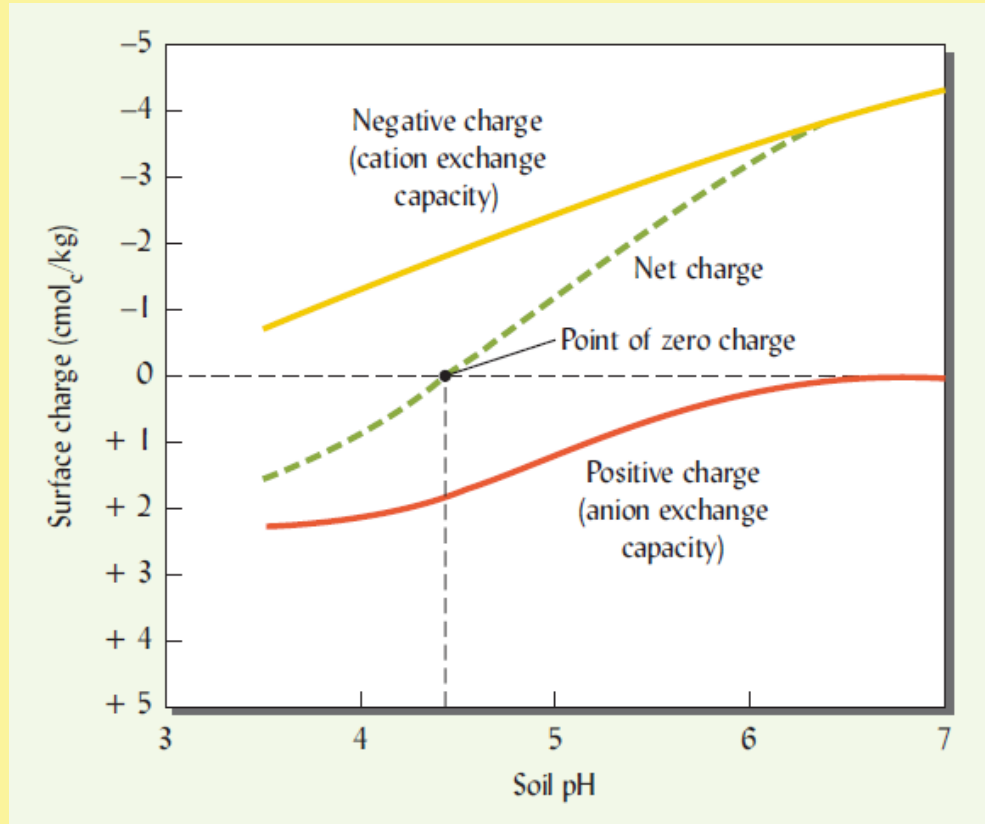
❑ Under low pH, edge oxygen associates with H+, hence a net positive charge

Charges in various clays

CHARGE CHARACTERISTICS OF REPRESENTATIVE COLLOIDS SHOWING COMPARATIVE LEVELS OF PERMANENT (CONSTANT) AND pH-DEPENDENT NEGATIVE CHARGES AS WELL AS pH-DEPENDENT POSITIVE CHARGES

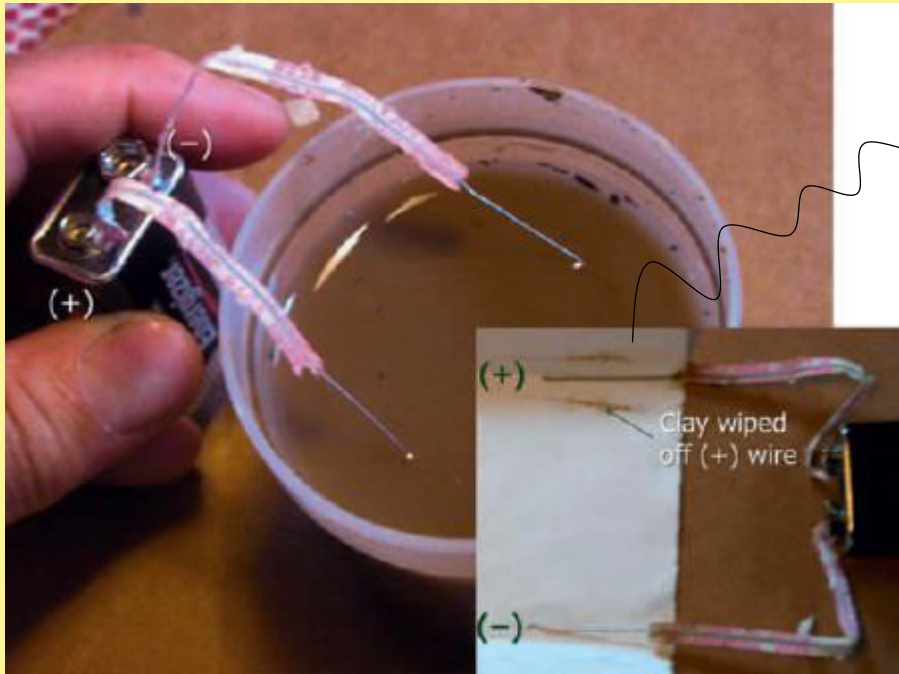
Colloid type	Negative charge			Positive charge, cmol _e /kg
	Total at pH 7, cmol _e /kg	Constant, %	pH dependent, %	
Organic	200	10	90	0
Smectite	100	95	5	0
Vermiculite	150	95	5	0
Fine-grained micas	30	80	20	0
Chlorite	30	80	20	0
Kaolinite	8	5	95	2
Gibbsite (Al)	4	0	100	5
Goethite (Fe)	4	0	100	5
Allophane	30	10	90	15

Relationship between soil pH and charges



- **Cation Exchange Capacity increases with increasing soil pH**
- **Anion Exchange Capacity decreases with increasing soil pH**
- **In acid rich 1:1 clay soils of tropical region, positive charges are more abundant whereas, negative charges predominate in 2:1 clays of temperate regions**

A negatively charged clay



Clay attracted to positive terminal, demonstrating its negative charge

Adsorption of cations and anions

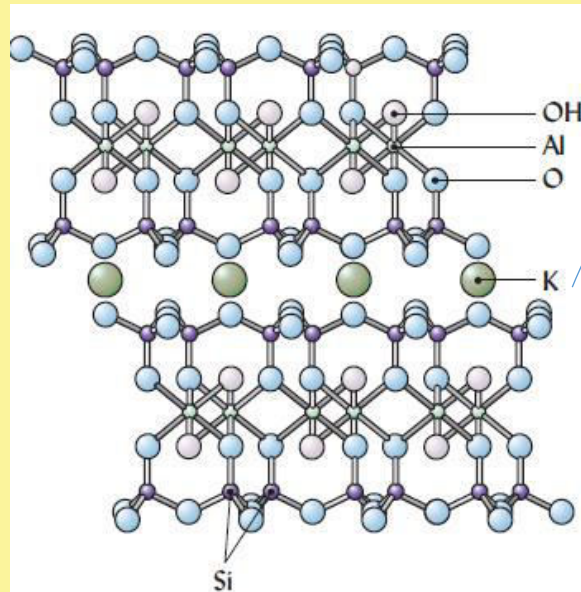
- Adsorption : adhesion of gases, ions or atoms to a surface
- May be physical or chemical
- Charged colloid surfaces adsorb cations and anions
- Two types of formations aid in adsorption – outer and inner sphere complex

Outer-sphere complex

- ❑ Ions are usually surrounded by water in soil solution
- ❑ Water molecules thus act as bridge between ions and colloid surfaces
- ❑ **Weak electrostatic force** binds the ions to colloids
- ❑ Hence, ions are easily replaced

Inner-sphere complex

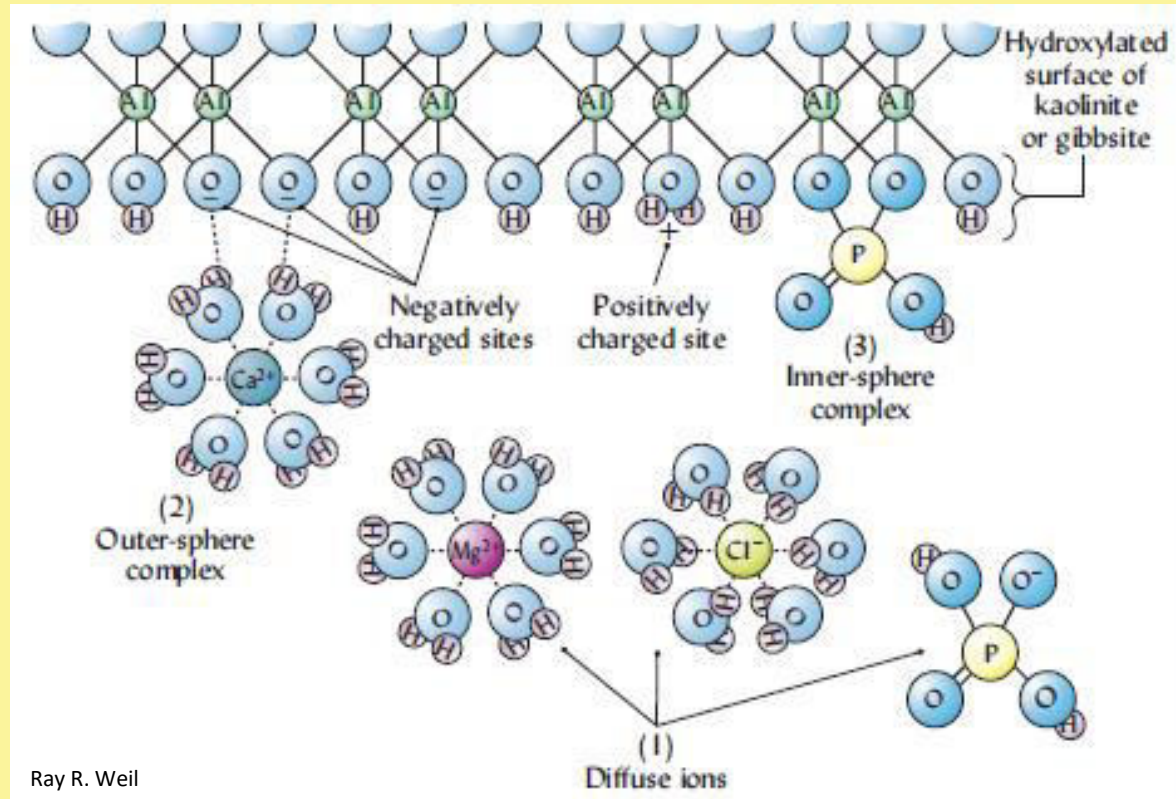
- ❑ No water molecules in between ions and colloids
- ❑ Hence, ions directly bond with colloidal surface
- ❑ Very difficult to replace ions



Tightly bonded K^+ ion

2:1 nonexpanding fine grained mica

Outer and inner-sphere complexes



Role of adsorption

□ The amount and type of cations adsorbed affect the fertility of soil

CATIONS AND ANIONS COMMONLY ADSORBED TO SOIL COLLOIDS AND IMPORTANT IN PLANT NUTRITION AND ENVIRONMENTAL QUALITY

The listed ions form inner- and/or outer-sphere complexes with soil colloids. Ions marked by an asterisk (*) are among those that predominate in most soil solutions. Many other ions may be important in certain situations.

Cation	Formula	Comments	Anion	Formula	Comments
Ammonium	NH_4^+	Plant nutrient	Arsenate	AsO_4^{3-}	Toxic to animals
Aluminum	Al^{3+} , AlOH^{2+} , Al(OH)_2^+	Toxic to many plants	Borate	B(OH)_4^-	Plant nutrient, can be toxic
Calcium*	Ca^{2+}	Plant nutrient	Bicarbonate	HCO_3^-	Toxic in high-pH soils
Cadmium	Cd^{2+}	Toxic pollutant	Carbonate*	CO_3^{2-}	Forms weak acid
Cesium	Cs^+	Radioactive contaminant	Chromate	CrO_4^{2-}	Toxic pollutant
Copper	Cu^{2+}	Plant nutrient, toxic pollutant	Chloride*	Cl^-	Plant nutrient, toxic in large amounts
Hydrogen*	H^+	Causes acidity	Fluoride	F^-	Toxic, natural, and pollutant
Iron	Fe^{2+}	Plant nutrient	Hydroxyl*	OH^-	Alkalinity factor
Lead	Pb^{2+}	Toxic to animals, plants	Nitrate*	NO_3^-	Plant nutrient, pollutant in water
Magnesium*	Mg^{2+}	Plant nutrient	Molybdate	MoO_4^{2-}	Plant nutrient, can be toxic
Manganese	Mn^{2+}	Plant nutrient	Phosphate	HPO_4^{2-}	Plant nutrient, water pollutant
Nickel	Ni^{2+}	Plant nutrient, toxic pollutant	Selenate	SeO_4^{2-}	Animal nutrient and toxic pollutant
Potassium*	K^+	Plant nutrient	Selenite	SeO_3^{2-}	Animal nutrient and toxic pollutant
Sodium*	Na^+	Used by animals, some plants, can damage soil	Silicate*	SiO_4^{4-}	Mineral weathering product, used by plants
Strontium	Sr^{2+}	Radioactive contaminant	Sulfate*	SO_4^{2-}	Plant nutrient
Zinc	Zn^{2+}	Plant nutrient, toxic pollutant	Sulfide	S^{2-}	In anaerobic soils, forms acid on oxidation

Reference:

- ❑ **The Nature and Properties of Soils by Nyle C. Brady and Ray R. Weil**