EPSc 413 SP17 Homework #3 ANSWER KEY

1. Properties of soil minerals.

a. Answers should include most of the following:

Kaolinite

i. 1:1 silicate clay
ii. Little to no isomorphous substitution/Sheets are neutral
iii. Does not expand and absorb water or cations
iv. Low surface area
v. Low CEC/Low Activity

Smectite

i. 2:1 silicate clay
ii. Isomorphous substitution/Layers have negative charge
iii. Interlayers hold water and cations
iv. Shrink and swell depending on water content of soil/Can more than double in size when wet
v. High surface area
vi. High CEC/High activity

Iron Oxides

i. Series of oxide minerals containing Fe^{3+}
ii. No substitution or layer charge
iii. Red, orange, or yellow in color
iv. Adsorb many ions on surface
v. Non-swelling/not sticky/stable

b. Kaolinite typically has much lower CEC values than smectite because kaolinite has little to no isomorphous substation. The layers remain neutral and do not attract other ions. In contrast, smectites have isomorphous substitutions that create negative layer charge. Cations enter the interlayers for to balance this charge. Smectite interlayers are hydrated and the cation are thus exchangeable. Kaolinite displays some CEC because of variably charged groups on the edges of kaolinite particles.

2. CEC and related soil parameters.

a. CEC = sum of charged ions = $Ca^{2+} + Mg^{2+} + Na^{+} + K^{+} + Al^{3+}$
Remember that you have to multiple the values for exchangeable cation concentrations by the charge of the ion.

Soil	Ca2+	Ca2+ (by charge)	Mg2+	Mg2+ (by charge)	Na+	Na+ (by charge)	K+	K+ (by charge)	Al3+	Al3+ (by charge)	CEC
A	1.9	3.8	3.7	7.4	0.1	0.1	0.1	0.1	5.6	16.8	28.2
B	7.4	14.8	3.6	7.2	1.3	1.3	0.3	0.3	0.6	1.8	25.4
C	0.6	1.2	0.4	0.8	0.3	0.3	0.2	0.2	1.2	3.6	6.1
D	3.9	7.8	2	4	6.9	6.9	0.9	0.9	0.9	2.7	22.3

b. % base saturation = $(Ca^{2+} + Mg^{2+} + Na^{+} + K^{+})/CEC$
Again, you use cation concentrations multiplied by their charge for this calculation.

Soil	% Base Saturation	% Acid Saturation (100-Base Saturation)
A	40.43	59.57
B	92.91	7.09
C	40.98	59.02
D	87.89	12.11

c. The mollic epipedon is sample B. This soil has the highest CEC, the highest base saturation, and the highest divalent ion content.

d. Need to calculate Na-saturation.

Soil	% Exchangeable Na+
A	0.35
B	5.12
C	4.92
D	30.94

The natric horizon is sample D. This soil has greater than 15% exchangeable Na^{+} (18.4%).

3. Adsorption processes

a. Cation exchange is a physical process where a clay mineral with a negative charge, typically caused by isomorphous substitution, attracts positively charged ions (cations). Surface complexation involves ions (positive or negative) forming chemical bonds with variable charge sites on mineral surfaces. Surface complexation is highly pH dependent whereas cation exchange is largely independent of pH.

b. Possible answers include: Na, Mg, K, Ca, Rb, Sr, Cs, Ba

c. Possible answers include: S, P, As, Se, Cr, Mo

4. Aluminum and soil acidity

a. Al^{3+} undergoes hydrolysis:
$Al^{3+} + H_2O \leftrightarrow AlOH^{2+} + H^+$
$AlOH^{2+} + H_2O \leftrightarrow Al(OH)_2^+ + H^+$
$Al(OH)_2^+ + H_2O \leftrightarrow Al(OH)_{3,gibbsite} + H^+$
Each of these steps produces 1 H^+, with a total of $3H^+$ generated upon complete hydrolysis. Because of hydrolysis Al^{3+} produces three times as much acidity as H^+.

b. Aluminum causes a lower CEC under acidic conditions by blocking cation exchange sites. This occurs when the $AlOH^{2+}$ and $Al(OH)_2^+$ hydrolysis products enter cation exchange sites. These will polymerize and block a large number of sites. As pH increases, these convert to gibbsite, re-exposing the exchange sites and increasing CEC.

c. CEC = 17 $cmol_c/kg$
acid saturation = 80% or 0.8
All acid saturation is from Al, so Al saturation = acid saturation = 80%
The amount of exchangeable Al is thus: 17 $cmol_c/kg$ * 0.8 = 13.6 $cmol_c/kg$
We want to reduce this to 20% acid saturation, which is 17 * 0.2 = 3.4 $cmol_c/kg$
We thus need to remove 13.6 – 3.4 = 10.2 $cmol_c/kg$ of aluminum by replacing this with calcium.
It would thus take 10.2 $cmol_c/kg$ of calcium to lower the acid saturation to 20%

5. Soil organisms
a. Multiple answers are possible. See textbook for possible correct answers.

b. Multiple answers are possible. See textbook for possible correct answers.

c. Multiple answers are possible. See textbook for possible correct answers.