Faculty of Engineering and Applied Science
Engi 7718 – Environmental Geotechniques

First Quiz , Open Notes — Instructor: Dr. C. A. Coles
Wednesday, 27 May 2009, 9:00 – 9:50 a.m.

There are 2 questions worth a total of 20 marks. Only non-programmable scientific calculators without text or graphics storage are permitted. Show all work.

Name:_____ Student ID:_____

1) Using the equation given below, determine the oxidation numbers of the elements in the three compounds containing iron and silicon. What type of chemical reaction is this and how is this reaction identifiable? (4 marks)

$$4FeSiO_3 + O_2 + H_2O \rightarrow 4FeO(OH) + 4SiO_2$$

Fe	Si	O^{2-}	Fe	O^{2-}	OH^-	Si	O_3^{2-}
+2	+4	−6	3+	−2	−1	+4	−4

Iron is oxidized from Fe^{2+} to Fe^{3+}.
oxidation reaction. (as discussed in paper with arsenic)

It is also an hydrolysis reaction since water reacts.

oxidation is loss of electrons → Fe^{2+} to Fe^{3+}
gain of oxygen → more oxygen in compounds on right side.
gain of hydrogen → more hydrogen in compounds on right side.

2) A clay soil is at a temperature of 15°C and it is permeated with a 2.5×10^{-4} M solution of $MgCl_2$ in water. The clay has a CEC = 40 meq/100 g and a SSA of 80 m^2/g.
   a) Find the DDL thickness in Å (5 marks)
   b) Find the surface potential in mV, and (6 marks)
   c) Find the potential at 50 Å from the clay surface. (5 marks)

(Total 16 marks)

CEC = 40 meq/100g 2.5×10^{-4} m $MgCl_2$
SSA = 80 m^2/g T = 15° C. in water

a) $n_0 = 2.5 \times 10^{-4} \frac{mol}{L} \times 6.023 \times 10^{23} \frac{ions}{mol} \times 1000 \frac{L}{m^3}$

$= 1.506 \times 10^{23} \frac{ions}{m^3}$

$T = 15 + 273 = 288$

$kT = 288\,K \times 1.38 \times 10^{-23} \frac{J}{K} = 3.974 \times 10^{-21}\ J$

$$\frac{1}{K} = \left(\frac{\varepsilon_0 D\, kT}{2\, n_0 e^2 v_i^2} \right)^{0.5}$$

$$= \left(\frac{7.083 \times 10^{-10}\ C^2/J\text{-}m \times 3.974 \times 10^{-21}\ J}{2 \times 1.506 \times 10^{23}\ ions/m^3 \times (1.602 \times 10^{-19}\ C)^2 \times 2^2} \right)^{0.5}$$

$= 95.4\ \text{Å}$

b) $\Gamma = \frac{40\ meq/100g}{80\ m^2/g} = \frac{40}{100} \frac{meq}{g} \times \frac{g}{80\ m^2} = 0.005 \frac{meq}{m^2}$

$\sigma = 96.5 \frac{C}{meq} \times 0.005 \frac{meq}{m^2} = 0.4825 \frac{C}{m^2}$

$$\sinh\left(\frac{z}{2}\right) = \frac{\sigma}{(8\, n_0\, \varepsilon_0 D\, kT)^{0.5}}$$

$$\sinh\left(\frac{z}{2}\right) = \frac{-0.4825\ C/m^3}{(8 \times 1.506 \times 10^{23} \frac{ions}{m^3} \times 7.083 \times 10^{-10} \frac{C^2}{Jm} \times 3.97 \times 10^{-21} J)^{0.5}}$$

$$= \frac{-0.4825}{0.0018406} = -262$$

$\frac{z}{2} = -6.26$; $z = -12.52$

$$\psi_0 = \frac{z\,kT}{v_i\,e} = \frac{-12.52 \times 3.97 \times 10^{-21}\ J}{2 \times 1.602 \times 10^{-19}\ C} = 0.155\ V = -155\ mV$$

c) $\frac{1}{K} = 95.4\ \text{Å}$; $K = 0.0105\ \text{Å}^{-1}$

$$e^{z/2} = e^{6.26} = 523.22$$

At 50 Å

$$e^{\psi/2} = \frac{523.22 + 1 + (523.22 - 1)e^{-0.0105 \times 50}}{523.22 + 1 - (523.22 - 1)e^{-0.0105 \times 50}}$$

(308.94) (0.5916)

$$= \frac{833.16}{215.28} = 3.87 = e^{\psi/2}$$

$$\psi/2 = 1.35, \quad y = 2.706$$

$$\psi = \frac{y\,kT}{v_i\,e} = \frac{2.706 \times 3.97 \times 10^{-21}\ J}{2 \times 1.602 \times 10^{-19}}$$

$$= 0.0335\ V = -33.5\ mV$$